TATA ENERGY RESEARCH INSTITUTE
BANGALORE

COMPREHENSIVE ENERGY AUDIT REPORT

OF

LARSEN & TOUBRO LIMITED
AWARPUR CEMENT WORKS, MAHARASHTRA

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LARSEN & TOUBRO LIMITED
AWARPUR CEMENT WORKS, MAHARASHTRA

"Comprehensive Energy Audit Report"

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EXECUTIVE SUMMARY

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1.0 INTRODUCTION

This report presents the findings of energy audit of M/s Larsen & Toubro Ltd , Awarpur Cement Works, Dist. Chandrapur, Maharashtra

Energy audit study was carried out during December 1996 with a team of consulting Engineers to identify energy saving opportunities in electrical energy consumption areas of plant

2.0 SUMMARY OF OBSERVATIONS

After the detailed energy audit, the preliminary observations and broad scope of energy saving potential was presented by the team to the plant management executives

An interim report for budgetary provisions to be made for investment oriented proposals was sent to the management immediately The plant has consumed about Rs 90 crores worth of electricity during 1995-96 for production of about 2.47 million tonnes of cement The average electricity consumption has been reported to be 117 kWh/t.

The detailed energy audit and recommendations given in the report has identified an energy saving potential of **5.56%** of Rs.90 crores of annual electricity costs The equivalent annual cost savings works out to **Rs. 5.00 crores.**

The investments required for implementation of the proposals has been worked out to be about **Rs.1.50 crores**, based on the in-house data available and the budgetary prices quoted by manufacturers /suppliers

The overall areawise summary of energy savings potential is given below :

Area	Annual Energy Savings	Cost savings	Investment reqd.	Payback period
	Electr. L.kWh	Rs. lakhs/y	Rs.Lakh	Years
Electrical System	9.88	42.74	12 7	< 1 yr
Fans and Blowers	105.08	315.38	37.40	< 1 yr
Compressed Air System	30.67	92.01	40.41	< 1 yr
Electric Drives	8 64	28.38	34 38	1 21
Refrigeration and Airconditioning /Canteen	1.65 t of LPG	0.40	2 4	6 06
Lighting System	7 40	21.53	23.65	1 09
Total	**161.67**	**500.44**	**150.44**	

The implementation of proposals in the above areas are expected to reduce energy consumption by **6.5 kWh/tonne** of cement

The study and summary of results presented above indicates that, through a systematic and committed action plan, it is possible to programme and implement the energy conservation proposals

3.0 ELECTRICAL SYSTEMS

A. Transformer Load Management

A review of utilisation of distribution transformer has yielded scope to divert two transformers of 1600 kVA capacity exclusively for lighting loads. The under-loaded 500 kVA transformer of mines office is also proposed to be diverted to lighting loads for optimum setting of distribution voltage The above proposal is discussed in detail in Section 8 0

B. 6.6 kV Bus Voltage Co-ordination

The measurement and analysis of 6.6 kV bus voltage levels indicate that 6 6 kV bus should be operated at 1% lower levels by changing the settings of automatic relay of on-load tap-changers for all the four power transformers

The setting should be adjusted to give an output of 6 54 kV in Ist stage and after implementing proposal of changing the large fans to high efficiency type, decreasing the voltage level to 6 54 kV should be tried out. The details of exercise carried out on MSS transformer No.3 - S/S 1 are given in Appendix - 3/7 and this base has been taken for quantification of the total system.

Implementation of 1% reduction in 6 6 kV bus voltage level is expected to yield monthly demand savings of 881 kVA and minimise distribution losses by 9.68 lakh kWh. The lowest estimate indicate energy costs reduction by Rs 29 7 lakhs per annum without any investment.

C. Power Factor Management

The average monthly power factor of the plant is 0.90 - 0.93. PF compensation is available on both 6.6 kV and 415 Volt bus, however the failure of capacitors are reported which is due to ageing. By optimum bus voltage co-ordination, it is possible to improve the peak load PF and hence the average P.F as detailed in Section 3 4 However plant management should periodically monitor the output and health of capacitor banks.

To improve the instantaneous /average PF to 0 94/0.96 and above, it is proposed to install additional 1950 kVAr of capacitors at various load centres. The implementation of above measure is expected to yield monthly demand savings of 690 kVA with an implementation cost of Rs.11 70 lakhs. Details are given in Section 3.6.

D. Distribution Losses

The electricity distribution losses are between 1.5 to 2.0%. The cable sizes used are optimal Multiple runs of cable are used in those places, wherever voltage drops are critical for the equipment and this is a good practice It is recommended to switch capacitor banks along with the motor drives and compensate the inductive loads at load end section. Implementation of the above proposal is expected to yield energy savings of 20,526 kWh with an investment of Rs.1.00 lakh. Details are given in Section 3.7.

E. Energy Metering Systems

The energy metering and power supply monitoring systems are to be provided for proper energy accounting and load management. State of the art instrumentation and monitoring helps in rational use of electricity achieving two goals

- Reduction in specific energy consumption
- Energy cost reduction.

Hence it is recommended to install energy monitoring system which is expected to cost Rs 30 to 40 Lakhs for the entire plant. Plant should review the necessity and benefits of such an installation. Details are given in Section 3 8.

4.0 FANS AND BLOWERS

A. Arresting False Air Entry in Fans Circuit

False air entry has been observed in various fan circuits of the plant This false air results in unnecessary loading of the fan and hence higher power consumption

By arresting the leakages in the circuit, considerable amount of energy can be saved. The false air quantification along with expected energy savings and cost savings by arresting them are tabulated below for various fans systems in both phases of production.

Sl No	Area / circuit	False Air Quantity Nm^3/h	Annual Energy Savings lakh kWh	Annual Cost Savings Rs. lakhs
1	Phase-I/Kiln ESP	2,07,908	16.23	48.70
2	Phase-I/Raw Mill	71,927	16.94	50.84
3	Phase-II / Kiln ESP	1,35,776	8.55	25.66
4	Phase-II/Raw Mill	53,291	11.56	34.68

Refer Section 4.2- B for techno-economics

B. Reducing Pressure Loss across fan dampers

The pressure loss across the dampers in fans listed below raises the total pressure across the fan and hence higher power consumption. This results in considerable loss of energy The existing pressure losses across dampers along with the recommendations to reduce the losses and energy saving potential are tabulated below.

Sl No	Area / Fan circuit	Existing pressure loss mmWg	Recommendations	Annual energy savings lakh kWh	Annual Cost Savings Rs lakhs
1	Phase - II Coal Mill Vent fan	520	Provide Gear box to reduce the fan rpm by 20% and open the damper fully	10 92	32 78
2	Phase - II Coal Mill Hot Gas fan	+ 116 before damper and - 110 after damper	Provide variable speed fluid coupling and open the dampers fully so that the positive pressure at fan outlet becomes negative	0 65	1 96
3	Phase -I Grate Cooler Fans and Phase - II Grate Cooler Fans	-	The inlet vane of cooler fan starting from 3rd compartment (i e W1K12 or W2K12) can be operated in combination with variable speed drives	8.87	26 61

Refer section 4.2 C for techno-economic details.

C. Replacement of Cooler ESP Fan in Phase - I with Correct Size and High Efficiency Fan

The cooler ESP fan in Phase - I was found to be 58% efficient. By replacing with high efficiency fan, considerable amount of energy savings can be achieved. (Refer Section 4 2 D). The implementation of above measure is expected to yield annual energy savings to the tune of 5.22 lakh kWh with an investment of Rs.8 lakhs, having a pay back period of less than one year.

D. Replacement of Cooler ESP Fan in Phase - II with Correct Size and High Efficiency Fan

The cooler ESP fan in Phase - II was found to be 49% efficient. By replacing with high efficiency fan considerable amount of energy savings can be achieved (Refer Section 4.2 D). The implementation of the above measure is expected to yield annual energy savings to the tune of 6 17 lakh kWh with an investment of Rs.8 lakhs, having a payback period of less than 6 months

E. Operation of Raw Meal Silo Top Bag Filter Fans

The bag filter fans on raw meal silo top in both phases were found to be in operation even though mechanical conveying (bucket elevator) is used for conveying material to silo. These fans can be stopped now thereby considerable amount of energy savings (Refer Section 4.2.E) i.e 5.06 kWh/year can be achieved The above proposal does not involve any implementation cost and the payback is immediate

F. Reduce Speed of Phase - I Primary Air Fan by 10% and replace Existing Damper with Inlet Guide Vane Control

The butterfly type damper is used for flow control in Phase -I primary air fan. In order to reduce the pressure loss across damper of 167 mm Wg, it is recommended to reduce the rpm of fan by 10% and thereby open the damper fully This will reduce pressure loss across damper resulting in 87,000 kWh of annual energy savings. (Refer Section 4 2.F). The investment required is marginal (Rs.40,000/-) and this is expected to payback in less than 2 months.

G. Replacement of Phase - II Primary Air Fan with High Efficiency Fan and Inlet Vane Control

This fan is found to be 48% efficient and also the inlet vane control used is not working satisfactorily By replacing this fan with high efficiency fan and inlet vane control, 1 64 lakh kWh of annual energy savings can be achieved. (Refer Section 4.2.G) The investment of Rs.3.00 lakhs is expected to payback in less than 1 year.

H. Operate Cement Mill - II ESP Fan (Z2P07) Similar to Other Cement Mill ESP Fans and Also Use Correct Size Fan

In cement mill - II the ESP fan is placed at a far off distance than required resulting in higher pressure and hence higher power consumption By placing it similar to other cement mill ESP fans, the pressure can be reduced. Also replacing this fan with correct size fan would result in total annual energy savings, of 2.90 lakh kWh of electricity The investment of Rs 2 00 lakhs is expected to payback in a few months.

I. Replace Cement Mill - III ESP Fan (Z3P05) with High Efficiency Fan

This fan is found to be 51% efficient, by replacing this with high efficiency fan, annual energy savings of 87,000 kWh can be obtained with an investment of Rs.2.00 lakhs giving a payback period of 10 months (Refer Section 4 2.I).

J. Replace Silo - 6 Top Fan (P2P69) in Packing House with High Efficiency Fan

This fan is found to be 41% efficient. By replacing this with high efficiency fan, annual energy savings of 71,000 kWh can be realised with an investment of Rs 2 00 lakhs and payback period of one year

K. Optimise Air Quantity Used for Conveying Coal to Kiln and Calciner

The air quantity used for conveying pulverised coal to Kiln and Calciner were found to be above the required amount in both phases This quantity can be reduced by reducing the rpm of blower in stages In order to maintain the velocity, the pipe size also has to be changed Optimising the air quantity results in considerable amount of energy savings (Refer Section 4 2 K) to the tune of 7 92 lakh kWh. The investment of Rs 4 00 lakhs is expected to payback in two months

COMPRESSED AIR SYSTEM

A. Improving Compressor FAD

The Atox mill area compressors K2U07, K2U11, Kiln 1-area compressor W2X10, Kiln 2-area compressor H2X02 and Envirocare compressors W1X12, W1X13, W1X14, W2X11 operate with lower FADs The FAD of compressors should atleast be 85% By proper maintenance, the FAD of these compressors could be improved above 85%. Refer section 5 2.(i) for details Detailed checklist for compressed air systems is enclosed in Chapter 10.0 for reference

The above measure is expected to yield annual energy savings to the tune of 4.46 lakh kWh The investment of Rs.3 50 lakhs required for spares is expected to payback in less than half a year.

B. Operating Only Two Low Pressure Compressors And Reducing The Pressure Setting To 1.2 kg/cm^2 (g)

In packing house, 3 LP compressors are operated, supplying air at 2 2 kg/cm^2 (g) for silo and packer aeration The FAD of these compressors are less than 85%. By improving the FAD to 85%, one compressor can be switched-off. Moreover, as the pressure required at the user point is only 1 0 kg/cm^2 (g), the delivery air pressure at the compressor can be set to 1.2 kg/cm^2 (g). Refer section 5 2.(vii) for details. The above measure is expected to yield annual energy savings to the tune of 5 68 lakh kWh with an investment of Rs 2.00 lakhs, paying back in less than half a year

C. Optimisation Of Compressed Air Usage In Cement Mill Area

Pipe conveyor is used for conveying cement from cement mill to silo for cement mill - I to III and whenever Special Grade Cement is manufactured in cement mill - IV, for which pneumatic conveying is used All the compressors in this area are designed for pneumatic conveying By optimising compressed air usage and replacing two high pressure compressors with one low pressure compressor and one lower capacity high pressure compressor, the specific power consumption can be reduced. Refer section 5 2.(viii) for details.

The above measure is expected to reduce total load of 183 kW giving annual energy saving of 14.49 lakhs kWh. The investment of Rs.29 00 lakhs is expected to payback in less than one year.

D. Operating Only Two High Pressure Compressors in Atox Mill Area

By improving the FADs of Atox mill area compressors K2U20, K2U21, K2U23 to 85%, it is possible to switch-off one of the compressors as the air delivered from the other two would be sufficient to meet the demand. Refer section 5 2.(ix) for details. The 36 kW electrical load released is expected to yield annual energy savings of 2.83 lakh kWh. The investment required being Rs.2.00 lakhs, the implementation of the proposal is expected to payback in less than half a year.

E. Use of Blower Air Instead of Compressed Air For Coal Conveying To Storage Bin In Atox Mill Area

In Atox mill section, compressed air at 0.8 kg/cm^2 (g) is used for conveying pulverised coal to the storage bin. Blowers can be used for such low pressure applications to reduce the power consumption per unit FAD Refer section 5 2 (x) for details. Implementation of the above proposal is expected to yield energy savings of 77,220 kWh with a payback of less than one year on an investment of Rs.2.00 lakh.

F. Replacing V-Belts of Compressor Motors with Flat Belts

V-belts used for power transmission in compressors can be replaced with flat belts, as V-belts cause power loss of about 5-10% of the absorbed power. Refer section 5.2 (xi) for details. The annual energy savings to the tune of 2.44 lakh kWh can be realised with an investment of Rs.1.91 lakhs, paying back in less than half a year.

6.0 ELECTRIC DRIVES

A. General

a It is suggested that for all important drives, suitable history cards be maintained for reference

b Necessary precaution during rewinding of motors should be taken (Details given during final presentation to the plant)

c In feasible cases, motor terminal based reactive compensation shall help in avoiding distribution loss

B. Star Mode Operation of Under-loaded Motors

The motors with active loading less than 35 - 40% may be run in `STAR' mode This will reduce the energy consumption and simultaneously improve the p f of operation because of reduced iron losses The results of energy savings are tabulated in Appendix 6/7, giving an annual savings of 68,793 kWh without any investment

A number of motors are loaded in the range of 35 - 40 % They are seldom operated above 50% loading as per process demands Adoption of Auto DELTA - STAR controllers (Operates in Star mode when the motor is under-loaded and changes over to Delta mode when motor load exceeds 40%) for these motors are expected to result in annual energy savings to the tune of 101658 kWh The investment cost of Rs 2 72 lakhs is expected to be paid back within a year

C. Optimum Sizing and Use of Energy Efficient Motors

It is observed that in Phase - I number of motors are grossly under-loaded and also operating at low p f. whereas for similar condition of loading in Phase - II, drives are operating at better level of p.f.

Implementation of optimum sizing and use of energy efficient motors has an annual energy savings potential of 6.63 lakh kWh. The investment of Rs 26 63 lakhs may be proposed in two phases giving a payback of 1.34 years

D. Energy Savings by Use of Electronic Energy Savers

The motors coupled to drives such as hammer mill, hydraulic pump, etc. are proposed to be connected with electronic energy saver. This will result in improved pf of operation, demand savings and improved operating efficiency (reduced motor heating).

The annual energy savings possible by implementing this measure is expected to be 30,486 kWh with 210 kVA maximum demand savings. The payback on Rs 5 03 lakhs of investment is expected to be less than 2 years

7.0 REFRIGERATION / AIRCONDITIONING & CANTEEN SYSTEMS

7.1 REFRIGERATION /AIRCONDITIONING

The review of energy efficiency in R & AC systems has brought about the following points that are to be closely examined/monitored

A. General

I) The removed nozzles from the cooling tower spray header and the remaining choked nozzles are to be replaced This improves the effectiveness of the cooling tower and subsequently the efficiency of the water cooled utilities.

II) AIR CURTAINS should be provided for the doors which are frequently opened and closed (eg ADM building front door, Central Control Room)

III) Direct heat load should be minimised by providing few more sun light control sheets for ADM building

IV) Treated water should be used as the chilled water make up to avoid scale formation in evaporator and chilled water lines to improve heat transfer.

V) Measures should be taken to avoid losses due to openings in the conditioned rooms

VI) It is necessary to have a dedicated cooling tower for Refrigeration units This will improve the performance of the condenser and hence the refrigeration units Actions have already been taken to provide a separate cooling tower for the refrigeration units

7.2 CANTEEN SYSTEMS

A. The hot water supply from existing solar water heating system is insufficient It is recommended to install additional solar flat plate collector water heating system of 2,000 lpd capacity, to generate more hot water The above proposal is expected to yield annual cost savings of Rs 39,600/- The investment of Rs 2 4 lakhs is paid back with in 6 06 years

8.0 LIGHTING SYSTEM

A. General

i The luminaires should be periodically cleaned and maintained. Regular replacement of worn-out tubes or luminaires are necessary to get maximum lumens per watt consumed.

ii. Switch `ON ' to match the occupancy level in office areas or stores etc.

iii Organise for improvement of lux level in certain areas by way of adopting simple measures as suggested in detailed text.

iv The plant maintenance should acquire a mechanical truck mounted telescopic platform for easy outdoor maintenance.

v. Suitable highmast lighting with increased efficacy can be organised for better illumination in the areas at the locations indicated in the Plant layout drawing

vi The plant should replace all Fluorescent fixtures in dusty areas by HPSV lamps

vii In the colony areas, reduction in the height of street lamp-posts should be taken - up

viii In junction or in important places of activity, re-introduction of 250W HPSV lamp and trimming of tree branches shall help in increasing the light level

ix Decodify incandescent lamps from Store inventory and install energy meter at important points e g Canteen, Guest House, Club etc

B. Energy Efficient Lighting

i Operation of lighting loads at reduced voltage through exclusive lighting transformers deployed from existing resources shall yield in annual energy savings (Appendix - 8/7) to the tune of 5.22 lakh kWh The investment for locating available 2x1000 KVA transformers, switchgears, cables etc Is expected to cost Rs 15 0 lakhs, giving payback of one year

ii Energy savings can be achieved through controlled switching by use of timers and by-passing circuit (Appendix - 8/9) as stated below :

Annual savings to the tune of 1 20 lakh kWh is obtained with an implementation cost of Rs 2 25 lakhs paying back in less than one year

iii By Simple "SWITCH OFF " method for lighting loads, the plant can prevent wastage of energy (Appendix - 8/10) to an extent of 28,322 kWh per annum Cost of implementation being Rs 1 00 lakh, this proposal is expected to have simple payback period of 1 year

iv Use of Electronic choke in controlled atmosphere and non dusty areas can yield savings of energy (Appendix - 8/11) as below

The annual energy savings are expected to be 71,280 kWh, with a cost of implementation of Rs 5 40 lakhs, having a payback period of 2 5 years

9.0 ENERGY MANAGEMENT SYSTEM

The aspects of energy management structure and approach are highlighted in detail in this section.

10.0 ACKNOWLEDGEMENT

On behalf of M/s Tata Energy Research Institute, the team of Consulting engineers would like to thank the management of M/s L & T Cements (ACW) for their co-operation and help extended during energy audit.

MAIN REPORT

LARSEN & TOUBRO LIMITED
AWARPUR CEMENT WORKS, MAHARASHTRA

COMPREHENSIVE ENERGY AUDIT REPORT

1.0 INTRODUCTION

This report presents the findings of energy audit of ***Larsen & Toubro Limited, Awarpur Cement Works, Maharashtra.***

Larsen & Toubro Limited, Awarpur Cement Works, has two streams for production, Phase - I commissioned in 1983 and Phase - II in 1987. Both these phases were upgraded in 1994 Presently Phase - I produces 4000 TPD clinker while Phase -II produces 4800 TPD clinker, totalling to 2 5 Million Tonnes of cement per annum

Both phases have dry process kilns incorporating precalcination technology

The plant is planning to go in for a captive power plant (2 x 23 MW capacity) by 1998 and also acquire their own coal mine in case Govt. Policy changes The construction of first phase of CPP is in progress.

Energy audit was carried out by our team of consulting engineers during December 1996 in the following areas to identify energy saving opportunities.

- Electrical Systems & Load Management
- Fans and Blowers
- Compressed Air System
- Electric Drives
- Airconditioning & Canteen Systems
- Lighting System

During the study, every attempt was made to understand the operational features and working of the project in proper perspectives. For the purpose of analysis, various operations were observed, relevant data collected, measurements taken wherever necessary, using portable instruments There was continuous interaction with the plant personnel, who gave full support to the study team

This report presents the analysis, findings and recommendations for achieving energy savings The techno-economic details are worked out for each case study and simple payback calculations are computed.

2.0 ENERGY CONSUMPTION PROFILE

2.1 PRODUCTION PROFILE

L&T, ACW produces ordinary portland cement - OPC 53 grade and grey portland cement (GPC) Details of the actual production for the past three years are tabulated below and monthwise production details are shown in Appendix - 2/1

Year	Cement production (Tonnes)
1993-94	22,16,520
1994-95	23,81,618
1995-96	24,71,558

2.2 ENERGY PROFILE

Electricity, Coal, LDO are the major sources of energy used in the plant Electricity is used for total plant operation, utilities, lighting etc Coal is used for kiln and calciner firing and LDO for firing of kiln.

The annual energy consumption for the past 3 years are given below

Year	Electricity Consumption (kWh)	Coal Consumption (Tonnes)	LDO Consumption (Litres)
1993 - 94	28,58,64,420	4,97,499	3,88,400
1994 - 95	30,48,22,991	5,24,940	2,54,189
1995 - 96	30,26,41,744	5,09,397	2,99,268

The specific power consumption in both phases of production is 117 kWh/ T of cement. Monthwise specific power consumption is given in Appendix -2/2 and department-wise specific power consumption from April 96 to Nov 96 is given in Appendix - 2/3.

3.0 ELECTRICAL SYSTEMS

3.1.1 FACILITY DESCRIPTION

A. General

L&T ACW's main source of Electricity supply is from Maharashtra State Electricity Board through a double circuit 66 kV transmission line 66 / 6 6 kV Main receiving station is located within the plant layout and houses four power transformers The details of main power transformers are given below

DETAILS OF POWER TRANSFORMERS - MAIN RECEIVING STATION

Details	Transformer No 1 & 2	Transformer No 3 & 4
Capacity MVA	16 / 20	20 / 25
Voltage Ratio kV	66 / 6.6 kV	66 / 6.6 kV
Make	Bharat Bijlee	Bharat Bijlee
Type of Cooling	ONAN / ONAF	ONAN / ONAF
Primary rated current (Amp)	175	218 7
Secondary rated current (Amp)	1674	2092
Vector group	Dyn11	Dyn11
Rated frequency -Hz	50	50
Mode of operation	Independent For phase I	Independent For phase II

The main 66 / 6 6 kV power transformers distribute power to 10 main sub-stations located closer to load centers The HT loads mainly comprising of 6 6 kV induction motors of large / medium size (approx. 39 nos) receive power through Power Control Centers housed in the respective sub stations

The 6.6 kV / 433 volt distribution transformers (29 nos.) located at various sub-stations are of different ratings mainly catering to LT distribution through Power Control Centers and Motor Control Centers with necessary isolators, circuit breakers, protective relays, measuring instruments etc., The LT loads mainly comprise of large / medium / small induction motors, welding equipments and lighting

The rating details of distribution transformers at various substations are tabulated below :

DETAILS OF DISTRIBUTION TRANSFORMERS

PHASE - I

Sl No	Phase - I (Sub-station)	Rating (kVA)	No of Transformers
1	HPC-1 Raw mill	1600	1
2	HPC-2 Coal mill	1600	3
3	HPC-2 Kiln feed	800	1*
4	HPC-2A Kiln feed	1600	3
5	HPC-3 Cement mill	1600	3
6	HPC-4 L S Crusher	750	1
7	Mines	1600	1
8	Township	750	4

* For DC motor thyristor converter

PHASE- II

Sl No	Phase - II (Sub-station)	Rating (kVA)	No.of transformers
1	SS-1 Raw mill	1600	2
2	SS-2 Coal mill	1600	2
3	SS-2A Coal mill	1600	3
4	SS-2A Kiln feed	1000	1*
5	Kiln feed SS-2B	1600	1
6	Cement Mill SS-3	1600	4

* For DC motor thyristor converter

Main Sub-Station

The main substation houses two transformers of 16/20 MVA and two transformers of 20/25 MVA with OLTC The four 6.6 kV bus section are independently operated Parallel operation of LT bus sections are not practised, to avoid any tripping due to fault The two transformers of 16/20 MVA cater to phase - I loads and the transformers of 20/25 MVA cater to phase - II loads

Raw Mill Sub-Station

Phase - I (HPC-1) has one transformer of 1600 kVA for raw mill auxiliaries and stacker The 6 6 kV feeders supply to two ball mill motors of 1800 kW

Phase - II (SS-1) has two transformers of 1600 kVA for raw mill auxiliaries and stacker reclaimer section The 6 6 kV feeders supply one large motor of 4000 kW for ball mill. The LT supply loads feed LS conveyors and shale yard.

Kiln-Feed Sub-Station

Phase - I (HPC-2A) has two transformers of 1600 kVA and 6 6 kV supply for HT motors One transformer of 800 kVA supplies power to converter of 435 kW DC motor

Phase - II (SS-2B) has one transformer of 1600 kVA and 6.6 kV outgoings for HT motors One transformer of 1000 kVA supplies power to converter of 540 kW D.C motor

Coal Mill Sub-Station

Phase - I (HPC-3) has three transformers of 1600 kVA and 6 6 kV outgoings to supply HT motors.

Lime Stone Crusher Sub-Station

Phase - I (HPC-4) has one transformer of 1000 kVA and two outgoings for crusher HT motor drives The outgoing feeders supply 1 x 500 kVA transformer at mines office and 4 x 750 kVA transformers of township

Cement Mill Sub-Station (HPC - 3 & SS - 3)

Power supply to Cement mill Phase - I and its auxiliaries is fed from HPC - 3 sub-station comprising of 3 x 1600 kVA transformers. The 6 6 kV drives of cement mill Phase - I receive supply from HPC-3 .

Power supply to Cement mill Phase - II and its auxiliaries is fed from SS - 3 sub-station comprising of 3 x 1600 kVA transformers.

Power supply to entire Packing plant equipments is catered by 1 x 1600 kVA transformer of HPC - 3 sub-station and by 1 x 1600 kVA transformer of SS - 3 sub-station respectively.

The sub-station - 3 feeders also supply power to coal yard and Coal crusher house

Mines Sub-Station

The Mines substation is located at about one KM from Main receiving station (MSS) with one transformer of 1600 kVA and two 6.6 kV motors for lime stone crushing

There are 2 phase lighting transformers giving lighting voltage of 250 volts for mine lighting There is also one transformer of 500 kVA for mines office and workshop fed by HPC-4 S/S of phase - I

Township Sub-Station

There are four sub-stations in the township, each having 1x750 kVA transformers supplying various domestic loads of quarters , lagoon pump house, guest house, club, effluent plants and street lighting.

Name plate details of Power and distribution transformers are presented in Appendix - 3/1.

B. Electricity Consumption Data

The power requirements of the complex is about 50 MW. Average p.f. of the installation is above 0.90 lag. The maximum demand recorded is around 56 MVA. The average monthly energy requirements are of the order of 200-260 lakh kWh depending on production

The monthly consumption data are summarised from Appendix - 3/2 as below :

Year	Max. kVA demand recorded	Max energy consumption lakh kWh	Highest PF recorded	Lowest pf recorded
1995 - 96	56670 (Dec'95)	303.27 (March'95)	0 937 (June'95)	0 90 (Jan'96)
1993 - 94	54062.5 (May'93)	286 68 (Oct'93)	0 943 (Nov'94)	0 907 (May'94)

The daily average energy consumption for a typical day i e for 6th August '96 is given below

Total consumption	93,0120 kWh
Max demand	50,000 kVA
PF	0 925
Load factor	83 80 %

The 66 kV incomer load parameters as measured on a typical day (13 12 96 to 14 12 96) is given below

Details	
66 kV load	400 - 480 Amps
MW load	40 - 48 MW
MVA load	45 - 52 MVA
AV PF	0 92 - 0 97
Feeder Voltage	60 6 - 63 5 kV
Frequency	48 - 50 9 Hz

3.1.2 Power Capacitors

Power Capacitors have been provided on 6 6 kV bus at MSS and other substations / motor drives for improvement of power factor The major electrical loads are induction motors used for fans and auxiliary drives. The load power factor is between 0 91-0 93 The 415 V LT capacitors at various sub-stations are at service in power control centres In some plants, the compensation is provided at the load end Details are given in Appendix - 3/3

3.1.3 Distribution System

Multiple runs of 3 core and 3 5 core 400 ,300,240 & 185 Sq.mm U G Cables have been drawn for main feeders depending on the loads catered by each feeder The sizes of cables used for sub feeders vary from 185 Sq.mm and below The secondary side output power from main and distribution transformers are taken through Aluminium bus duct system to main bus of PCC panels

3.1.4 Expansion Plans

There is no proposal for immediate expansion plan as it has been recently carried out in the year 1994. However, efforts are being put to achieve optimum production in Phase - II .

The plant is adding captive power generation capacity of 2 X 25 MW The generation voltage will be at 6 6 kV and the power will be distributed to the present main receiving station by double bus arrangement

3.2 OBSERVATIONS, ANALYSIS AND FINDINGS

3.2.1 Measurements

For the purpose of study, measurements have been taken using various meters and measuring instruments The portable power and demand Analyser has been used extensively to measure the electrical parameters at various points Measurement was carried out at substations, LT Panels, transformer feeders, HT feeders and at feeders of major power consuming equipments The Plant has very elaborate and systematic record / book keeping of all necessary data of distribution equipment Necessary data has been collected from Registers / documents maintained

3.2.2 System Parameters

The measurements of load parameter of incoming 66 kV system was carried out on 13 /14th December using CT and PT terminals of incomer panel

The general consumption pattern, Variation of Maximum Demand and the Power Factor has been shown in Appendix - 3/4, depicting 66 kV MSEB incomer load parameters.

The incoming voltage profile has been indicated in Appendix - 3/5a. for a typical working day The OLTCs of the main power transformers are in service, and voltage variation has been observed to be from 60 kV to 64 kV. Variation in load current, frequency, PF, MW / MVA load w.r.t. time is plotted respectively in the graphs represented in Appendix - 3/5 b - f.

Analysis of Load parameters over the day indicate that the overall load factor is 89 46% The corresponding loss load factor is assumed to be 0.85. Details of calculations are given in Appendix - 3/6

The monthly average Power Factor varies between 0 91 and 0.93.

3.2.3 Tariff Details

The details of electricity tariff are as under

As on 1st ,Dec'96

Avg kWh charges	=	Rs 2.92 per kWh
kVA (Max demand) charges	=	Rs 150/-
Sanctioned kVA (Max demand)	=	59,000 KVA
Overall charges on energy	=	Rs 3 00/kWh**

** Taken from total bills paid and energy consumed from grid .

3.3 TRANSFORMER LOAD MANAGEMENT

3.3.1 General

All the four power transformers are operated on load without any standby The load on all distribution transformers can be changed over by parallel operation during exigencies/breakdowns, without interruption The operating p f. of outgoing transformer feeders were observed to be above 0 92 lag, with capacitor banks in circuit.

The details of loading of all distribution transformers of Production Plants were taken for, typical working day. All plant substation including MSS are unmanned and continuous instantaneous power data of large loads of all substations is monitored at Electrical Computer section. Periodical maintenance of data logging in all substations must be initiated

A. Incoming Power Transformer 66 kV / 6.6 kV System

The secondary voltage of power transformer is maintained at 6 6 kV by adjustment of sensing circuit on on-load tap changer. The voltage bandwidth is set at 66 kV + 1%

The record of number of operations of each OLTC was not available, however this will be useful data which should be maintained by installing a counter The above data indicates health of grid and helps in regular analysis of the optimum bandwidth for voltage conversion, to minimise losses

The observed loading pattern of power transformers is satisfactory Load of 23-25 MVA of Phase - I is shared by 2 X 16/20 MVA transformers Load of 25-28 MVA of Phase - II is shared by 2 X 20/25 MVA transformers The percentage loading of power transformers have been observed to be above the economic levels The transformers are not operated in parallel The operating p f of loads were observed to be above 0 92, thus minimising the I^2R losses of the power transformers There is scope for further improvement in load p f and this has been discussed in subsequent chapters

B. Distribution Transformers (All of 1600 kVA Capacity)

The details of loading and observation remarks are highlighted in the following table for phase-I and phase-II respectively.

Phase - I Loading of distribution Transformers

Substation reference	Transformer kVA Rating	Trf ID Code No.	% load (approx.)
HPC -1 Raw mill	1 x 1600	T11	< 35
HPC - 2, Kiln motor	1 x 800	T24	50
HPC - 2A, Kiln feed	2 X 1600	T-A1	20
		T-A2	35
HPC - 2 Coal mill	3 X 1600	T21	30
		T22	50
		T23	25
HPC - 3 Cement mill	3 x 1600	T31	30
		T32	30
		T33	35
HPC - 4 L S Crusher	1 x 1000	T41	40
Mines Substation mines office	1 x 1600	-	< 30
	1 X 500	-	10 - 20
Township Substation	4 x 750	-	10 - 20

Phase - I

From the above tables, it is observed that the loading of transformers in kiln feed, coal mill and cement mill are below 30 - 40%

The Plant has adopted the advanced mechanical conveying system in place of pneumatic conveying systems which were in operation earlier, consuming more power The Pneumatic conveying system is kept as emergency standby for any eventuality of breakdown of mechanical belt / bucket conveying system

In mines office/workshop, the 500 kVA transformer installed for office/ workshop is loaded very low and is proposed for decommissioning. Mines office/workshop loads could be supplied by utilising the LT cables laid from HPC - 4 substation. The released 500 kVA transformer is proposed to be installed in township substation and subsequently releasing 1 x 750 kVA transformer at township substation.

Phase - II Loading of distribution Transformers

Substation Reference	Transformer kVA Rating	Trf ID. Code No.	% load (approx)
SS -`1 Raw mill	2 x 1600	T11	30
		T12	20
SS - 2 Coal mill	1 x 1600	T22	40
SS - 2A Coal mill	2 x 1600	T2A-1	40 - 50
		T2A-2	60
	1 x 1000	T2A-3	60 - 70
SS - 2B Kiln feed	1 x 1600	T2B-1	40
SS - 3 Cement mill and Packing Plant	4 x 1600	T32	< 10
		T33	< 25
		T35	< 10
		T36	40

From the above tables, it is observed that the loading of transformers in kiln feed, coal mill and cement mill are between 40 - 60%

In Phase - II also mechanical conveying system has been adopted in place of pneumatic conveying systems which were in operation earlier consuming more power The Pneumatic conveying system serves as emergency standby for any eventuality of breakdown of mechanical belt / bucket conveying system In Phase - II loading of transformers is higher compared to Phase - I, due to production enhancement in Phase - II production

Release of 1 x 1600 kVA transformer in SS - 3 Cement mill substation (which is found usually under-loaded) and 1 x 1600 kVA transformer already released at SS - 2B, can be utilised as lighting transformers exclusively The 1 x 750 kVA transformer released from township substation can also be connected for lighting loads. The above transformers can also cater to plant welding loads in addition to plant lighting loads (Refer Chapter on Lighting)

3.4 Optimum Bus Voltage Co-ordination

A. 6.6 kV Bus Voltage Systems

From the recording of incoming voltage and load profiles the lowest voltage recorded is 59 76 kV and the highest recorded is 63.6 kV on a typical working day The setting of the voltage regulation relay of the OLTC's of four power transformers are in auto mode with a time delay. Under normal voltage conditions, the setting would result in a secondary voltage of rated 6 6 kV and some times as high as 6 7 kV due to switched capacitor banks on 6 6 kV bus

Analysis of the graphs for a typical working day indicate that the present voltage levels on 6 6 kV bus is always higher than 6.6 kV.

Detailed measurement of power parameters were carried out on S/S-2 Phase- I for assessing the impact of optimising 6 6 kV bus voltage levels by ·

* Operating the OLTC's to raise /lower voltage levels
* Connecting power analyser with on-line monitoring on 6 6 kV incomer at S/S-2 supplied by transformer No.3 (Phase - II)
* The load on the feeder was maintained constant for ½ hour

The results of observations (while operating OLTC on incoming transformers) taken on a printer/computer are placed in Appendix - 3/7.

For a 6 MW operating load, the following analysis is tabulated based on the operating load parameters at 6.6 kV as reference.

➔ When the voltage is increased beyond 6.6 kV by 1%

* The reactive power drawn from grid has increased by 84 kVAr
* The P F. of incomer has remained at 0.95
* The kVA demand has shown marginal increase (439 kVA)

➔ When the voltage is at 6 6 kV + 2%

* In addition to above observations, the pf of load has dropped by 1% reactive load has increased by 123 kVAr.

➔ When the voltage is reduced by 1% on 6 6 kV bus

* The reactive power drawn has reduced by 125 kVAr
* The PF of incomer has improved by 1%
* The kVA demand has shown reduction by 115 kVA
* The kW load has dropped by 18 kW in addition to above changes

➔ When the voltage is reduced by 2% on 6 6 kV bus

* The reactive power drawn has reduced by 371 kVAr
* The PF incomer has improved by 2%
* The kVA demand has reduced by 115 kVA as above

From the above, by maintaining optimum voltage levels on 6 6 kV bus in MSS on all the four transformers at 6 54 kV level, it is possible to obtain system benefits and energy/cost savings by

* Reduction in kVA M D
* Reduction in distribution losses (Mainly due to reduced magnetic losses in motors)
* Improvement in system PF and reduced demand for reactive power drawn from grid
* Reduction in kVA loading of transformer and hence losses.

This aspect of optimising voltage levels on medium voltage bus has been widely practised by industries to obtain envisaged efficiency in electricity distribution practice

However, the plant management has indicated plans to install high efficiency fan systems for the plant with a budgetary proposal. In view of the above proposal, it is recommended that plant management should immediately lower the voltage by one step i e, 1% After implementation of proposed high efficiency fan installations it is recommended that 2% reduction in 6 6 kV system voltage should be tried out The following table gives quantification of the system benefits for the entire plant network (46 MW load) by reducing the voltage level by 1% For details of calculations please refer to Appendix - 3/8

Monthly reduction in maximum demand	= 881 kVA
Reduction in reactive power drawn ie , from grid	= 950 kVAr
Annual reduction in distribution losses (due lowering of magnetic losses of motors and losses is 29 distribution transformers)	= 9,68,430 kWh

This reduction in reactive power withdrawal helps to avoid incurring a capital expenditure to an extent of Rs.5.75 lakhs.

However the requirement of reactive power compensation for improving system peak load PF is dealt in Chapter 3.5 ;

B. L T Bus Voltage Levels on 415 V Bus

The off load tap settings on distribution transformers are observed to be maintained generally at tap No 3 or 2 The secondary voltage levels were measured to be in the range of 425 - 430 Volts to drive motors rated at 415 V and 3 phase lighting loads This is on the higher side resulting in increased magnetic losses in drives and lowering operating pf of load

The off load tap settings are to be rationalised depending on loading levels of transformers This has to be viewed vis-a-vis the reactive compensation made available on L T PCC bus, which also raises the LT distribution voltage by a few volts (Upto 4-8 volts observed)

After implementing the recommendations given in section 3 6 A, to lower the 6 6 kV bus voltage down by 1%, it is suggested that plant management should consider optimising the LT 415 Volts distribution voltage levels

It is recommended that the LT distribution voltages should be in the order of 415 Volts or less at the far end of feeder for obtaining optimal operation of LT electric drives and lighting loads.

5 Power Factor Management

The monthly average power factor of the plant has varied between 0.9 to 0.93 during the last year Plant has installed about 9,789 kVAr of capacitor banks on 6.6 kV bus and 4712 kVAr of capacitor banks on 415 Volts bus. The break-up of substation-wise installation of capacitor banks are given below

Phase - II - kVAr Capacity of Banks

Substation	6 6 kV System	415 V Bus
SS-1	3395	650
SS-2	1027	650
SS-2A	393	850
SS-2B	4524	1075
SS-3	450	1075
Mines	450	200

Phase - I - kVAr Capacity of Banks

Substation	6 6 kV System	415 V Bus
HPC-1	2172	286
HPC-2 & 2A	940	625
HPC-3	2616	-
HPC-4	482	150

Most of the 6 6 kV capacitor banks are switched with the motor and rated as per manufacturers recommendations However due to ageing of capacitor banks and failure of capacitor banks, replacement of faulty units are being carried out During measurements, the output of certain 6.6 kV bus connected capacitors were calculated, however these calculations did not tally with the rating of banks installed.

Reduction in output of capacitor banks has been observed inspite of maintaining 6.6 kV bus voltage level at 100% voltage. All the above observations indicate that ·

* There is deterioration of output due to ageing and leakages
* The faulty banks have not been replaced

A regular monitoring and history cards giving data on date of installation, failure record and analysis has to be maintained so that corrective actions may be initiated from time to time

As reported during discussions, the failure rate of capacitor banks has been observed to be on the increase This is also evident from the fact that the monthly average p f. of the plant is lowering from 0 93 to 0 91 This downward trend has to be arrested by installing additional HT 6 6 kV and LT 415 Volt capacitor banks at various load centres

Analysis of average / peak load pf of plant and details of calculations are given in Appendix - 3/9

It is recommended to install 1950 kVAr of additional capacitor banks for the system to improve the peak load pf of plant to above 0.94 and average monthly pf of plant to 0 96 and above

The implementation of above measure should be considered in addition to the replacement of existing faulty capacitor banks in plant

Further study "harmonic analysis of distribution network" should be initiated by plant since large thyristor drives and electronic controllers are available which may contribute to distortion of power parameters and losses

5 Distribution Losses

The plant has made use of multiple runs of cables of various sizes for HT/LT systems all over the plant The design of providing optimum no. of runs and cable sizes have been adopted to keep the voltage drop to the lowest minimum ,and hence the distribution losses have been calculated to be minimum Multiple cable runs have been provided even to the large motor drive loads This is a very good practice

However an effort has been made to compute the losses in motor feeders on 415 Volt systems using the elaborate data made available by plant and taking details of the measurements carried out (using a software).

The details are given in Appendix - 3/10 By installing the proposed capacitor banks at motor load feeders, (wherever feasible) it is possible to minimise distribution losses in the system As an immediate measure, plant is advised to shift part of unswitched LT capacitor banks to motor feeders.

7 On-Line Automation in Energy Metering and Energy Management

A. General

State of-the-art instrumentation and monitoring helps in rational use of electricity, achieving two goals

⇒ Reduction of specific energy consumption
⇒ Energy cost reduction

The extensive use of electronic energy-metering / process data recording and analysis enables the plant to explore hidden energy saving potential.

Energy information and related saving measures are introduced as daily exercises backed up by a permanent energy management team. It has been recorded by industries that it is possible to conserve 1- 4% of annual electricity consumption Additionally, equal percentage points of reduction in specific energy consumption can be projected as savings objective for the next year, by proposing action plans on process changes, efficient technologies and retrofits

Cement companies in Europe have been taking the expertise of management and consulting companies The measures implemented by them are ·

* Energy Control through Load Control (ECLC)

The operation of equipments must be constantly monitored and controlled This could be initially programmed by having on-line data of number of equipments operating in the section The on-line monitoring of operating equipment, (loading and energy consumption pattern) indicates when and where corrective actions are necessary

These corrective actions include

* Automatic load switching
* Preparation of instructions for manual operation by control room operator

Many plants in India have installed on-line monitoring of energy consumption.

B. Energy Data Information and Advisory Reports (EIAR)

The analysis of energy data of various equipments gives a constant feedback on complete energy picture The comparative estimates of trends gives rise to the following ·

* Checks the impact of energy saving measures
* Pinpoints weak spots in energy usage
* Creates an easily accessible database for energy usage
* Permits revision of production plans and schedules
* Facilitates establishment of new instructions for operating schedule of equipment

C. Metering System for Electrical Parameters

The large power distribution network of plant should have the following systems for effective monitoring and implementation of energy management programme

* Supervisory control and data acquisition system for MSS 66/6 6 kV station

  Microprocessor based panel mounted indicating and recording instrument for all HT and load feeder panels.

* Portable power monitoring and recording instruments for HT and LT systems, for energy management exercises

(i) SCADA System for MSS and Other Substations

Supervisory control and data acquisition system for power receiving, Distribution & generation system should be installed for power network. The following aspects of power management could be effectively carried out.

- Management of power factor by optimal compensation of reactive loads

- Bus voltage co-ordination to exercise control on the voltage of operation.

- Helps on line monitoring of data and carries demand / energy management during power cuts.

The above suggestions for implementation would cost around Rs.40.00 lakhs (approx.) and management should consider the long range benefit gained by such efficient operation of power supply distribution network which would assist in :

* Improved and accurate energy accounting and control

* Automatic generation of reports, charts eliminating the need for additional man power deployed round the clock to manually note the parameters

* Quick realisation of variations in consumption pattern possible since hourly, daily reports can be prepared and composed

* Eliminates the need for printing costly stationary and storing logbook data.

(ii) Microprocessor Based Indicating Meters

Installation of microprocessor based instrumentation at load feeders of respective substations, shall help in complete monitoring of all parameters including p f, kW, kVA, kVAr and cumulative energy consumption equipment wise. This will also eliminate the necessity of maintaining inventory of electromechanical meters and maintenance effort required. Higher levels of accuracy and precise reading in digital form can be had to the satisfaction of staff maintaining the systems

(iii) Portable Energy Management Systems

The plant management should procure one portable power monitoring and recording instrument This instruments should be utilised on both H T and L T systems so that on line measurement of instantaneous parameters are possible on both single and three phases Such instruments will cost Rs 50,000 for LT 415 V system and Rs 1 00 lakh for a high voltage system

However, installation of test terminal blocks on all important HT outgoing panels makes it easy to carry out such measurements

D. Restructuring of Energy Metering Systems

Initially, cost centres need to be identified It may be that 80 - 100 energy meters may need to be installed in a large plant With these energy meters, when connected to a computer with a package driven software, it is possible to down-load the energy parameter in given formats In this way, many plants are proposing to create a database which can indicate "bad days" and "good days" of any monthly or yearly period.

In one of the European examples highlighted by Ms Holderank Systems in a cement plant, they have brought out the concept of defining normal days (normal η), good days (high η), zero days (no production but remarkably high consumption).

Here, the wasted energy for operating idle equipment needs a closer look. Many processes consume energy, remarkably, high enough even on zero production days However, a quick review of plant equipment operating schedule and operating parameter will indicate the means for switching off idling equipment

For all the above function two things are important

- ⇒ Computers providing useful information
- ⇒ People acting accordingly

The block diagram of microprocessor based systems are given in Appendix - 3/11.

The plant layout has been considered and after subsequent discussions with some of the suppliers of such microprocessor based energy metering/power monitoring system, a proposal has been drawn, for installation as given in the block diagram For details of estimates and feasibility of supply of hardware/software, the manufacturers may be contacted whose addressees are given in Appendix - 3/12.

The above proposal is expected to cost anywhere between Rs 30 to 40 Lakhs however a budgetary provision for the same could be made in the two phases Plant may review the indirect benefits and necessity of such systems (as outlined in 3.7 A, B and C) before taking up this project.

PROPOSAL :

The proposal covers the 50 MW electricity distribution network, as per the layout of the plant

1. HPC - 3 of Cement Mill Substation of Phase - I
2. Phase - I, HPC - 1 Raw Mill Substation
3. Phase - I, HPC - A Crushing Plant Substation
4. Phase - I, HPC - 2 Coal Mill Substation
5. Substation 3 and 3A - Cement Mill feeding PCC - 3, 3A & 5 of Phase - II
6. Substation - 1, Phase - II, Raw Mill Substation
7. Phase - II Substations 2 and 2A of Kiln and Coal Mill
8. Phase - II, HPC 2A - Kiln Feed

METERING STRUCTURE

The details of feeders and layout have been studied and also the aspects of distances have been accounted The scheme gives the meter from a sub-station at one corner and stopped at a place nearer to the load centre, where the meters are to be read on a computer

The proposal involves about 15 Nos of main meters and about 29 Nos of transmitters at various substations communicating with most of the MCCs and HT motor drives, since most of the data has been generated with the assistance of system house specialists of few manufacturing companies It is mentioned that the management may get in touch with these companies for site specific requirements (Addresses given in Appendix - 3/12) The schematic details of substationwise metering referred are given in Appendix - 3/13 for reference

3.8 RECOMMENDATIONS

A. Transformer Load Management

The power and distribution transformers are optimally loaded. Since air compressor loads kept as standby, a review of utilisation of distribution transformer has yielded scope to divert two transformers of 1600 kVA capacity exclusively for lighting loads The under-loaded 500 kVA transformer of mines office is also proposed to be connected to lighting loads for optimum setting of distribution voltage. The above proposal is discussed in detail in Section 8 0

B. 6.6 kV Bus Voltage Co-ordination

The measurement and analysis of 6 6 kV bus voltage leveis indicates that 6 6 kV bus should be operated at 1% lower levels by changing the settings of automatic relay on on-load changers for all the four power transformers

The setting should be adjusted to given an output of 6 54 kV in Ist stage and after carrying out the proposal of changing the large fans to high efficiency type, decreasing the voltage level to 6 48 kV should be tried out The details of exercise carried out on MSS transformer No 3 - S/S 1 are given in Appendix - 3/7 and this has been quantified for the total system

Implementation of 1% reduction in 6.6 kV bus voltage level is expected to yield energy savings

Reduction in monthly maximum demand on incomer	= 881 kVA ....(a)
Reduction in reactive power demand from grid	= 950 kVAr
Annual reduction in distribution losses	= 9,68,430 kWh.....(b)
Annual cost savings (50% of (a) and 75 % of (b) taken)	= Rs.29.7 Lakhs

C. Power Factor Management

The average monthly power factor of the plant is 0.90 - 0.93. PF compensation is available on both 6 6 kV and 415 Volt bus, however the failure of capacitors are reported which is due to ageing BY optimum bus voltage co-ordination, it is possible to improve the peak load PF and hence the average P F as detailed in Section 3.4 However plant management should periodically monitor the output and health of capacitor banks

To improve the instantaneous /average PF to 0 94/0 96 and above, it is proposed to install additional 1950 kVAr of capacitors at various load centres The implementation of above measure is expected to yield annual energy savings as below .

Savings in maximum demand	= 690 kVA
Annual savings in electricity bill	= Rs 12.42 Lakhs
Cost of implementation	= Rs 11 70 Lakhs
Simple payback period	= Less than 1 year

Details are given in Section 3 6.

3.9. SUMMARY OF POTENTIAL SAVINGS

Sl No	Recommendations	Annual Energy Savings		Investment requirement	Simple Payback period
		kWh	Rs. in Lakhs	Rs in Lakhs	Year
1	6 6 kV Bus Voltage Co-ordination	8 81 kVA & 9,68,430 kWh	29 7	Nil	Immediate
2	Power Factor Management	690 kVA Max Demand	12[redacted]	11 7	Less than 1 yr
3	Distribution Losses	20,526	0 62	1 00	1 year
Total		**9,88,956**	**42.74**	**12.7**	**Less than a year**

4.0 FANS AND BLOWERS

4.1 FACILITY DESCRIPTION

Large size and medium size fans are used mainly for process and venting applications like preheater, ESP, mill, cooler, etc., while small size fans are used for dedusting in silos, packers, DBC, etc. The fans used for different applications in L&T, ACW and their design parameters are :

PHASE - I

Fans	Equipment Code	Quantity (m3/min)	Total static pressure (mm Wc)	Motor rating (kW)
Calciner String smoke gas fan	J1JO1	6500	800	1800
Kiln String smoke gas fan	J1JO3	4100	800	950
Kiln ESP Fan	J1P44	12600	95	600
Raw Mill Fan	R1PO5	3900	610	700
Cooler ESP Fan	W1P51	9700	175	425
Coal mill vent fan	K1P56	860	620	160
Primary Air Fan	W1VO7	400	720	110
Cooler Fan - 1	W1K10	595	1000	225
Cooler Fan - 2	W1K11	950	1000	225
Cooler Fan - 3	W1K12	730	900	225
Cooler Fan - 4	W1K13	820	850	225
Cooler Fan - 5	W1K14	855	770	225
Cooler Fan - 6	W1K15	1020	650	225
Cooler Fan - 7	W1K16	2530	480	315
Cooler Fan - 8	W1K17	2530	405	325

PHASE - II

Fans	Equipment Code	Quantity (m3/min)	Total static pressure (mm WG)	Motor rating (kW)
Calciner String smoke gas fan	J2JO1	6950	815	1650
Kiln String smoke gas fan	J2JO3	4100	620	825
Kiln ESP Fan	J2P09	12300	140	500
Raw Mill Fan	R2PO5	4200	675	825
Cooler ESP Fan	W2P31	10700	180	600
Coal mill vent fan	K2T01	2875	1256	600
Primary Air Fan	W2VO7	149	1300	90
Cooler Fan - 1	W2K10	620	750	132
Cooler Fan - 2	W2K11	870	700	225
Cooler Fan - 3	W2K12	940	650	225
Cooler Fan - 4	W2K13	845	560	225
Cooler Fan - 5	W2K14	845	560	132
Cooler Fan - 6	W2K15	830	480	132
Cooler Fan - 7	W2K16	2710	350	225
Cooler Fan - 8	W2K17	1660	250	132

The fans used are both induced (Preheater, ESPs mill), as well as forced type (cooler) The design parameters of these fans are given in Appendix - 4/1

Twin lobe compressors (Roots blowers) are used for conveying pulverised coal from F K Pump/C P Pump to kiln and calciner for firing. The roots blower details are

Equipment Code	Quantity (m^3/h)	Delivery Pressure (mm Wg)	Motor Rating (kW)
W1U43	4650	6500	160
W1U45	4315	9000	150

4.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Flow Measurement

The quantity of hot gas/ air handled by each fan was measured using S-type Pitot tube & U-tube Manometer by measuring static pressure, velocity pressure (dynamic pressure) and temperature at the suction side for process fans and cement mill ESP fans and on delivery side for Packer dedusting fans. For cooler fans, primary air fans and Roots Blowers the velocity of air inlet was measured using Anemometer and inlet area was measured. From this the flow was found out.

METHODOLOGY ADOPTED FOR MEASUREMENT OF PARAMETERS IN FAN

For example, let us consider Phase- I calciner string smoke gas fan.

1 Static pressure, Dynamic pressure (Velocity pressure) and temperature are measured at the sample point for each fan using Pitot tube, U-tube manometer and thermocouple

The measured parameters for Phase - I Calciner string smoke gas fan are :

Static pressure

Static pressure		
	Suction side	= - 852 mm Wg
	Delivery side	= + 10 mm Wg
Dynamic pressure		= 25 01 mm Wg (rms value)
Temperature		= 304 °C
Duct diameter		= 2 4 m

2 The density of air or gas at fan inlet (sample point) can be known from N T P. values (1 4 kg/Nm^3 or 1 29 kg/Nm^3) by temperature and pressure correction.

Density of preheater gas = 1 4 kg/Nm^3

Density of air = 1 29 kg/Nm^3

Density of the gas at sample point can be known by the formula ·

$$\rho_2 = \rho_1 \times \frac{T_1}{T_2} \times \frac{P_2}{P_1}$$

ρ = Density in kg/m^3
P = Pressure in mm Wg
T = Temperature in Kelvin

Suffix -1 = Represents parameters at NTP

ρ_1 = 1 4 kg/Nm^3

P_1 = 1 bar = 10330 mm Wg

T_1 = 0 °C = 273 K

Suffix - 2 = Represents measured parameters at sample point

$$\rho_2 = 1.4 \times \frac{273}{(273 + 304)} \times \frac{(10064 - 852)}{10330}$$

(L&T, ACW is situated at 217 m from MSL and so atmospheric pressure is 740 mm Hg = 10064 mm Wg).

$\therefore$ Density at sample point, $\rho_2 = 0.591\ kg/m^3$

3. From Dynamic pressure & density at sample point, velocity can be obtained from the formula

$$V = C \times \sqrt{\frac{2 \times g \times h}{\rho}}$$

Where, C = Pitot factor (0 86)
g = Acceleration due to gravity m/s^2
h = Dynamic pressure, mm Wg
ρ = Density at sample point (kg/m^3)

$$V = 0\ 86 \sqrt{\frac{2 \times 9\ 81 \times 25\ 01}{0\ 591}}$$

$$= 24\ 78\ m/s$$

4 By knowing the area, the quantity of flow (Q in m^3/s) can be known by ·

Q = A x V
A = Area (m^2)
V = Velocity (m/s)

$$Q = \frac{\Pi}{4} \times (2\ 4)^2 \times 24.78$$

$$= 112\ 1\ m^3/s$$

$$= 4{,}03{,}566\ m^3/h$$

The quantity of flow at NTP (Nm^3/h) can be known by ;

$$= 403566 \times \frac{\text{Density of gas at fan inlet (sample point)}}{\text{Density of gas at NTP}}$$

$$= 403566 \times \frac{0.591}{1.4}$$

$$= 1{,}70{,}363\ Nm^3/h$$

Since fans operate at different conditions, in order to compare them it is essential to know the flow in Nm^3/h

The methodology adopted for fan measurements is given in Appendix - 4/2 in detail

The measurements were taken up individually for all fans and final measurement was taken on the same day for all process fans taking into consideration the condition of kiln and feed

	Kiln Feed	Raw Mill Feed
Phase - I	275 TPH	310 TPH
Phase - II	360 TPH	330 TPH

The false air in raw mill circuit is arrived from the difference in measured flow of kiln ESP fan (Nm^3/h) when raw mill is in operation and when it is not in operation.

The difference in measured flow (Nm^3/h) between smoke gas fans and kiln ESP fan indicate the false air in kiln ESP circuit including GCT.

Wherever dampers are used for flow control like cooler fans of both phases and phase - II coal mill vent fan and hot gas fan, the static pressure was measured before and after damper to arrive at pressure loss across damper.

All these measurements like excess air in circuit, pressure loss across damper is finally quantified in terms of excess power consumption by the fan

The measured parameters for Phase - I and Phase - II are summarised and given in Appendix - 4/3 and 4/4 respectively.

B. Arresting False Air in Kiln ESP & Raw Mill Circuit

The false air entry into the circuit has been observed at many joints of fan ducts. The following observations and analyses of computations is highlighted

PHASE - I

Total flow of smoke gas fans	=	2,78,163 Nm^3/h
Flow of kiln ESP fan when raw mill is not in operation	=	4,86,071 Nm^3/h.
Flow of kiln ESP fan when raw mill is in operation	=	5,57,998 Nm^3/h.

The measured flow indicates a difference of 2,07,908 Nm^3/h (when raw mill is not in operation) and 2,79,835 Nm^3/h (when raw mill is in operation) between smoke gas fans and kiln ESP fan. This excess air which is the false air in the circuit accounts for 16.94 lakh kWh per annum in raw mill circuit and 16 23 lakh kWh per annum in GCT, Kiln ESP circuit. The details are given in Appendix - 4/5

PHASE - II

Total flow of smoke gas fans	=	2,83,720 Nm^3/h
Flow of kiln ESP fan when raw mill is not in operation	=	3,66,205 Nm^3/h
Flow of kiln ESP fan when raw mill is in operation	=	4,19,496 Nm^3/h.

The measured flow indicates a difference of 82,485 Nm^3/h (when raw mill is not in operation) and 1,35,776 Nm^3/h (when raw mill is in operation) between smoke gas fans and kiln ESP fan This excess air entry has to be arrested immediately so that the unnecessary load to the fan and hence power consumed by the fan can be reduced. This excess air which is the false air in the circuit accounts for 11 56 lakh kWh per annum in raw mill circuit and 8 55 lakh kWh per annum in GCT, Kiln ESP circuit. The details are given in Appendix - 4/6

C. Reducing Pressure Loss Across Damper in Fan Systems

By reducing the speed for Phase -II coal mill vent fan and hot gas fan or by combined operation of damper and speed reduction VSD for cooler fans, the pressure loss across damper can be minimised

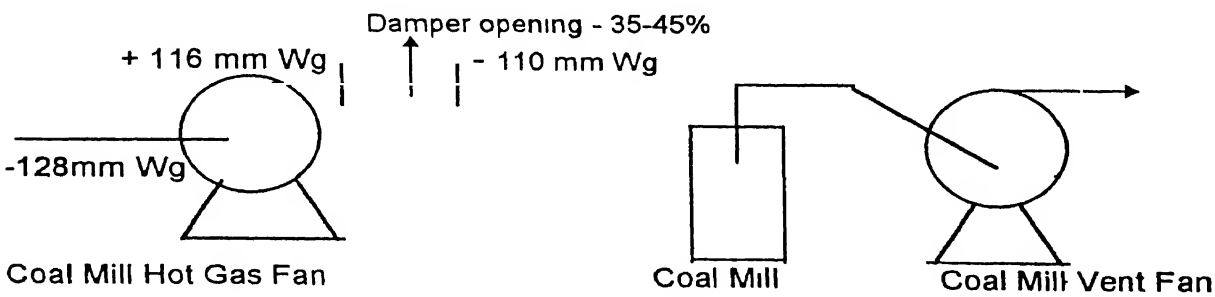
1. Phase - II Coal Mill Vent Fan

In Phase - II coal mill vent fan, the damper is operated at 56%. The static pressure before damper is - 822 mm Wg after damper it is - 1342 mm Wg and thereby a pressure loss of 520 mm Wg is observed across damper.

By reducing the present rpm of 992 to 794 ie., by 20% the damper can be opened to more than 90%. Hence reduction in pressure loss and power consumption can be achieved. This measure is expected to save energy to the extent of 10 92 lakh kWh per annum The details are given in Appendix - 4/7.

2. Phase - II Coal Mill Hot Gas Fan

In Phase -II coal mill hot gas fan, the damper is on the delivery side of the fan and is operated between 35-45%. While delivery (positive) pressure of + 116 mm Wg is observed before damper, suction (negative) pressure of - 110 mm Wg is observed after damper. (Refer Figure). This is due to the influence of coal mill vent fan



By varying the rpm using variable speed fluid coupling the damper can be opened fully and hence the vent fan influence extends till the delivery of hot gas fan. This results in reduced total static pressure and hence reduced power consumption by hot gas fan by 11 kW resulting in energy savings of 0 65 lakh kWh per annum. The details are given in Appendix - 4/8.

3. Phase - I and II Grate Cooler Fans

In Phase -I and II grate cooler fans, inspite of having variable speed drives the inlet guide vane controls (dampers) are also operated Considering the process conditions, the cooler fans except K10 and K11 can be operated at reduced speed as discussed with plant management and thereby increasing the damper opening i.e , by combined operation of damper and speed reduction This will reduce the pressure loss across damper and hence power consumption by 112 kW in both Phases resulting in energy savings of 8 87 lakh kWh per annum. The details are given in Appendix - 4/9

D. Replacement of Cooler ESP Fans in Both Phases with Correct Size & High Efficiency Fans

In Phase - I and Phase - II, both the cooler ESP fans were found to be oversized and also less efficient Out of 134 mm Wg total static pressure in Phase - I, 95 mm Wg accounts for pressure loss across damper and out of 122 mm Wg total static pressure in Phase - II, 82 mm Wg accounts for pressure loss across damper The present efficiencies of Phase - I and Phase - II fans are found to be 58% & 49% respectively These fans can be replaced with correct size and high efficiency fans resulting in energy savings of 5 22 lakh kWh per annum for Phase - I and 6.17 lakh kWh per annum for Phase - II The details are given in Appendix - 4/10.

E. Operation of Raw Meal Silo Top Bag Filter Fans

The bag filter fans on raw meal silo top in Phase - I and II were operated continuously in both phases even when bucket elevator is used for conveying material. These fans can be stopped when bucket elevator is in operation as there is a separate dedusting fan for bucket elevator. A suitable interlocking arrangement can be done to prevent simultaneous operation of bag filter fan and bucket elevator dedusting fan The energy loss due to the operation of this fan is 5.06 lakh kWh per annum The details are given in Appendix - 4/11.

F. Reduce Speed of Phase - I Primary Air Fan by 10% and Replace Existing Damper with Inlet Guide Vane Control

In Phase - I primary air fan, presently butterfly type of damper is used for flow control and the damper opening is 56% The pressure loss across damper is 167 mm Wg, the static pressure being - 5 mm Wg before damper and -172 mm Wg after damper This pressure loss can be minimised by reducing the rpm of fan by 10% and opening the damper fully. Also, the present inlet damper is to be replaced with inlet guide vane control These measures are expected to save energy to the extent of 0 87 lakh kWh per annum The details are given in Appendix - 4/12. The qualitative comparison of various control systems are given in Appendix - 4/13

G. Replacement of Phase - II Primary Air Fan with High Efficiency Fan and Inlet Guide Vane Control

From the measured parameters of flow and pressure the theoretical power consumption for the fan is 22.3 kW while measured power is 58 kW Assuming motor efficiency as 80%, the fan efficiency comes to only 48%

Also, the inlet guide vane has to be replaced with a new one as the performance of present inlet guide vane is not satisfactory. Replacing the present fan with high efficiency fan and inlet guide vane control is expected to save energy to the extent of 1.64 lakh kWh per annum. The details are given in Appendix - 4/14.

H. Operate Cement Mill - II ESP Fan (Z2PO7) Similar to Other Cement Mills ESP Fans and Also Use Correct Size Fan

In cement mill - II, the ESP fan (Z2PO7) is placed at a far off distance from the ESP resulting in a higher pressure (256 mm Wg) at the suction side compared to other similar fans (maximum of 174 mm Wg) and hence higher power consumption By placing it like other cement mill ESP fans (near ESP itself), the pressure and hence power consumption will be reduced Also the efficiency of the fan was found to be around 58%. Replacing it with correct size and high efficiency fan, the energy savings to the extent of 2 90 lakh kWh per annum can be achieved The details are given in Appendix - 4/15

I. Replace Cement Mill - III ESP Fan (Z3 PO5) with High Efficiency Fan

From the measured parameters of flow and pressure the theoretical power consumption for the fan is 16 kW while the measured power is 35 1 kW Assuming motor efficiency as 90% the fan efficiency comes to only 51% By replacing it with high efficiency fan (η = 75%) energy savings to the extent of 0 87 lakh kWh per annum can be achieved. The details are given in Appendix - 4/16

J. Replace Silo - 6 Top Fan (P2P69) in Packing House with High Efficiency Fan

From the measured parameters of flow and pressure, the theoretical power consumption was found to be 4.33 kW, while that of measured power is 14 9 kW Assuming motor efficiency as 70%, the fan efficiency is only 41%

By replacing this fan with high efficiency fan (η = 75%) energy savings to the extent of 0 71 lakh kWh per annum can be achieved. The details are given in Appendix - 4/17

K. Optimise Air Quantity Used for Conveying Coal to Kiln & Calciner

Twin lobe compressors (Roots blowers) are used for conveying pulverised coal from F K Pump/C P Pump to kiln and calciner The measurements indicate that the quantity used is higher than the norm In order to optimise the quantity of air used for conveying it is suggested to reduce the quantity of air by reducing the rpm of blower in stages Also it should be ensured that the present velocity is maintained by changing the present pipe size The energy savings to the extent of 7 92 lakh kWh can be achieved The details are given in Appendix - 4/18

4.3 RECOMMENDATIONS

A. Arresting False Air in Phase - I Kiln ESP Circuit

False air entry has been observed in Phase - I Kiln ESP circuit The difference of 2,07,908 Nm^3/h between smoke gas fans and kiln ESP fan clearly indicates the amount of false air in the circuit By arresting the leakages in the circuit, considerable amount of energy can be saved. (Refer Section 4 2 B).

Annual Energy Savings	= 16 23 Lakh kWh
Annual Cost Savings	= Rs 48 70 Lakhs
Investment required	= Marginal
Simple Payback Period	= Immediate

B. Arresting False Air in Phase - I Raw Mill Circuit

The false air entry of 71927 Nm^3/h has been observed in Phase - I Raw mill circuit By arresting the leakages in the circuit, considerable amount of energy can be saved (Refer Section 4 2 B)

Annual Energy Savings	= 16 94 Lakh kWh
Annual Cost Savings	= Rs 50 84 Lakhs
Investment required	= Marginal
Simple Payback Period	= Immediate

C. Arresting False Air in Phase - II Kiln ESP Circuit

False air entry has been observed in Phase - II Kiln ESP circuit The difference of 1,35,776 Nm^3/h between smoke gas fans and kiln ESP fan clearly indicates the amount of false air in the circuit. By arresting the leakages in the circuit, considerable amount of energy can be saved. (Refer Section 4 2 B)

Annual Energy Savings	= 8 55 Lakh kWh
Annual Cost Savings	= Rs 25 66 Lakhs
Investment required	= Marginal
Simple Payback Period	= Immediate

D. Arresting False Air in Phase - II Raw Mill Circuit

The false air entry of 53291 Nm^3/h has been observed in Phase - II Raw mill circuit. By arresting the leakages in the circuit, considerable amount of energy can be saved (Refer Section 4 2.B).

Annual Energy Savings	=	11 56 Lakh kWh
Annual Cost Savings	=	Rs 34.68 Lakhs
Investment required	=	Marginal
Simple Payback Period	=	Immediate

E. Reduce Pressure Loss Across Damper in Phase - II Coal Mill Vent Fan

The pressure loss across damper is found to be 520 mm Wg By using gear box, the rpm can be reduced by 20% and thereby the damper can be opened fully Hence, pressure loss across damper can be eliminated and considerable amount of energy can be saved. (Refer Section 4 2 C, 1)

Annual Energy Savings	=	10 92 Lakh kWh
Annual Cost Savings	=	Rs 32 78 Lakhs
Investment required	=	Rs 4 00 Lakhs
Simple Payback Period	=	2 Months

F. Reduce Pressure Loss Across Damper in Phase - II Coal Mill Hot Gas Fan

The static pressure before damper is + 116 mm Wg while after damper it is - 110 mm Wg By using variable speed fluid coupling, the damper can be opened fully and hence the positive pressure at fan outlet becomes negative ie , suction takes place at fan outlet due to the influence of vent fan (Refer Section 4 2 C,2)

Annual Energy Savings	= 0 65 Lakh kWh
Annual Cost Savings	= Rs 1 96 Lakhs
Investment required	= Rs 4.00 Lakhs
Simple Payback Period	= 2 04 years

G. Reduce Pressure Loss Across Damper in Phase - I and II Grate Cooler Fans

The inlet vane controls of cooler fan starting from 3rd compartment (i e, W1k12 or W2K12) can be operated in combination with variable speed drives By reducing the speed, the inlet vane control can be opened fully (Refer Section 4 2 C,3)

Annual Energy Savings	= 8 87 Lakh kWh
Annual Cost Savings	= Rs 26 61 Lakhs
Investment required	= Nil
Simple Payback Period	= Immediate

H. Replacement of Cooler ESP Fan in Phase - I with Correct Size and High Efficiency Fan

The cooler ESP fan in Phase - I was found to be 58% efficient By replacing with high efficiency fan considerable amount of energy savings can be achieved (Refer Section 4 2 D).

Annual Energy Savings	= 5 22 Lakh kWh
Annual Cost Savings	= Rs 15 68 Lakhs
Investment required	= Rs 8 00 Lakhs
Simple Rayback Period	= 7 Months

I. Replacement of Cooler ESP Fan in Phase - II with Correct Size and High Efficiency Fan

The cooler ESP fan in Phase - II was found to be 49% efficient By replacing with high efficiency fan considerable amount of energy savings can be achieved (Refer Section 4 2 D)

Annual Energy Savings	= 6.17 Lakh kWh
Annual Cost Savings	= Rs 18 53 Lakhs
Investment required	= Rs 8 00 Lakhs
Simple Payback Period	= 6 Months

J. Operation of Raw Meal Silo Top Bag Filter Fans

The bag filter fans on raw meal silo top in both phases were found to be in operation even though mechanical conveying (bucket elevator) is used for conveying material to silo These fans can be stopped now and thereby considerable amount of energy savings can be achieved (Refer Section 4 2 E).

Annual Energy Savings	= 5 06 Lakh kWh
Annual Cost Savings	= Rs 15 18 Lakhs
Investment required	= Nil
Simple Payback Period	= Immediate

K. Reduce RPM of Phase - I Primary Air Fan by 10% and Replace Existing Damper with Inlet Guide Vane Control

The butterfly type damper is used for flow control in Phase -I primary air fan In order to reduce the pressure loss across damper of 167 mm Wg, it is recommended to reduce the rpm of fan by 10% and thereby open the damper fully This will reduce pressure loss across damper resulting in considerable amount of energy savings (Refer Section 4 2.F)

Annual Energy Savings	= 0 87 Lakh kWh
Annual Cost Savings	= Rs 2 61 Lakhs
Investment required	= Rs 0 4 Lakh
Simple Payback Period	= 2 Months

L. Replacement of Phase - II Primary Air Fan with High Efficiency Fan and Inlet Vane Control

This fan is found to be 48% efficient and also the inlet vane control used is not working satisfactorily By replacing this fan with high efficiency fan and inlet vane control, considerable amount of energy savings can be achieved (Refer Section 4 2 G)

Annual Energy Savings	= 1 64 Lakh kWh
Annual Cost Savings	= Rs 4.94 Lakhs
Investment required	= Rs.3.00 Lakhs
Simple Payback Period	= 8 Months

M. Operate Cement Mill - II ESP Fan (Z2P07) Similar to Other Cement Mill ESP Fans and Also Use Correct Size Fan

In cement mill - II the ESP fan is placed at a far off distance than required resulting in higher pressure and hence higher power consumption. By placing it similar to other cement mill ESP fans, the pressure can be reduced Also replacing this fan with correct size fan results in considerable energy savings. (Refer Section 4.2.H)

Annual Energy Savings	= 2 90 Lakh kWh
Annual Cost Savings	= Rs.8 71 Lakhs
Investment required	= Rs 2 00 Lakhs
Simple Payback Period	= 3 Months

N. Replace Cement Mill - III ESP Fan (Z3P05) with High Efficiency Fan

This fan is found to be 51% efficient, by replacing this with high efficiency fan considerable amount of energy savings can be achieved (Refer Section 4 2 I)

Annual Energy Savings	= 0 87 kWh
Annual Cost Savings	= Rs 2 61 Lakhs
Investment required	= Rs 2 00 Lakhs
Simple Payback Period	= 10 Months

O. Replace Silo - 6 Top Fan (P2P69) in Packing House with High Efficiency Fan

This fan is found to be 41% efficient, by replacing this with high efficiency fan considerable amount of energy savings can be achieved. (Refer Section 4 2 J)

Annual Energy Savings	= 0.71 kWh
Annual Cost Savings	= Rs 2 13 Lakhs
Investment required	= Rs 2.00 Lakhs
Simple Payback Period	= 12 Months

P. Optimise Air Quantity Used for Conveying Coal to Kiln and Calciner

The air quantity used for conveying pulverised coal to Kiln and Calciner were found to be above the required amount in both phases. This quantity can be reduced by reducing the rpm of blower in stages. In order to maintain the velocity the pipe size also has to be changed. This reduction in quantity results in considerable amount of energy savings. (Refer Section 4 2.K).

Annual Energy Savings	= 7 92 kWh
Annual Cost Savings	= Rs.23.76 Lakhs
Investment required	= Rs 4.00 Lakhs
Simple Payback Period	= 2 Months

4.4 SUMMARY OF POTENTIAL SAVINGS

Recommendations	Annual Energy savings		Investment requirement Rs.in Lakhs	Simple Payback period
	Lakh kWh	Rs in Lakhs		
rresting False Air in Phase - I Kiln ESP ircuit	16 23	48.70	Marginal	Immediate
rresting False Air in Phase - I Raw Mill ircuit	16 94	50.84	Marginal	Immediate
rresting False Air in Phase - II Kiln SP Circuit	8 55	25 66	Marginal	Immediate
rresting False Air in Phase - II Raw Iill Circuit	11 56	34 68	Marginal	Immediate
educe Pressure Loss Across Damper 1 Phase - II Coal Mill Vent Fan	10 92	32 78	4 00	2 Months
educe Pressure Loss Across Damper 1 Phase - II Coal Mill Hot Gas Fan	0 65	1.96	4 00	2 04 Years
educe Pressure Loss Across Damper 1 Phase - I & II Grate cooler fans	8 87	26 61	Nil	Immediate
eplacement of Cooler ESP Fan in 'hase - I with Correct Size and High fficiency Fan	5 22	15 68	8.00	7 Months
eplacement of Cooler ESP Fan in 'hase - II with Correct Size and High fficiency Fan	6 17	18 53	8 00	6 Months
)peration of Raw Meal Silo Top Bag ilter Fans	5.06	15.18	Nil	Immediate
educe RPM of Phase - I Primary Air 'an by 10% and Replace Existing)amper with Inlet Guide Vane Control	0 87	2 61	0 40	2 Months
eplacement of Phase - II Primary Air an with High Efficiency Fan and Inlet Guide Vane Control	1 64	4 94	3 00	8 Months
)perate Cement Mill - II ESP Fan Z2P07) Similar to Other Cement Mill SP Fans and Also Use Correct Size an	2 90	8 71	2 00	3 Months
eplace Cement Mill - III ESP Fan Z3P05) with High Efficiency Fan	0 87	2.61	2 00	10 Months
eplace Silo - 6 Top Fan (P2P69) in 'acking House with High Efficiency Fan	0 71	2.13	2 00	12 Months
)ptimise Air Quantity Used for conveying Coal to Kiln and Calciner	7 92	23.76	4 00	2 Months
TOTAL	105.08	315.38	37.40	

5.0 COMPRESSED AIR SYSTEMS

5.1 FACILITY DESCRIPTION

The plant has 8 numbers of compressor houses located at different buildings in both the phases in total Totally there are fifty compressors in both the phases put together The details of the compressors operated are given below

Sl No	Comp House	Type of Compr	No of Compr Used	Rated Capacity m^3/min	Rated Pres kg/cm^{2}g	Usage	Stand -by comp	Remarks
1	Packing House	Recipro -cating	3	27 6	3 0	Silo, Packer, Packer Hopper Aeration	1	
		Recipro -cating	1	13 84	10 5	Operating Valves & Filters	2	
2	Cement Mill - 1	Recipro -cating	-	-	-	-	4	Earlier used for Fluxo-Pump
	Cement Mill - 2	Recipro -cating	1	31 41	5 0	Water Spray for CM-1 & CM-2	3	Earlier used for Fluxo-Pump
3	Cement Mill - 3	Recipro -cating	1	30 64	6 0	Water Spray for CM-3 & Filters	5	Earlier used for Fluxo-Pump
	Cement Mill - 4	Recipro -cating	4	30 64	6 0	Water Spray for CM-4 & Fluxo-Pump	2	-
4	Ph-II Atox Mill	Recipro -cating	2	11 58	2 0	C P Pump	2	-
		Recipro -cating	3	6 6	8 5	Filters & Pneumatic Gates	1	-
5	Ph-I Kiln - 1	Recipro -cating	2	13 81	10 5	Vital Equipments & Filters	1	-

Sl No	Comp House	Type of Compr	No of Compr Used	Rated Capacity m^3/min	Rated Pres kg/cm^2g	Usage	Stand -by comp	Remarks
6	Ph-II Kiln - 2	Recipro -cating	1	13 81	10 5	Vital Equipments & Filters	-	-
		Recipro -cating	1	10 20	10 0		-	-
		Recipro -cating	1	4 44	8 5		-	
		Recipro -cating	-	6 60	8 5		1	-
7	Ph-I Enviro Care	Screw	3	26 25	8 0	GCT, Kiln & Calciner Downcomer duct	1	-
8	Ph-II Enviro Care	Screw	2	26 25	8 0	GCT, Kiln & Calciner Downcomer duct	2	-

The plant was originally designed with pneumatic conveying of cement from cement mill to silo But now the conveying system is converted to mechanical type Hence most of the compressors in cement mill areas are kept as standby compressors The plant has sufficient number of standby compressors The specifications of all the compressors are given in Appendix - 5/1

5.2 OBSERVATIONS, ANALYSIS AND FINDINGS

i. Free Air Delivery (FAD) Test

FAD test was conducted to assess the actual air delivery of all the compressors which were operating during the study period The method of testing and FAD calculation details are given in Appendix - 5/2 The details of the compressors with FAD less than 85% are tabulated below ·

Sl. No.	Compressor	Design FAD m^3/h	Actual FAD m^3/h	% FAD delivered
	Packing House			
1	P2X10	27.6	18.22	66
2	P2X11	27 6	22.70	82
3	P2X12	27 6	20.95	76
	Atox Mill Area			
4	K2U07	11 58	7.56	65.3
5	K2U11	11.58	8 49	73.3
6	K2X20	6.6	3 99	60.5
7	K2X21	6 6	3 91	59.2
8	K2X23	6 6	3.80	57 6
	Kiln 1 - Area			
9	W2X10	13 81	9.54	59 6
	Kiln 2 - Area			
10	H2X02	13 81	8.23	60.0
	Phase 2 - Enviro Care			
11	W1X12	26.25	16 95	64.6
12	W1X13&14	26 25+26.25	40 17	76.5
	Phase 2 - Enviro Care			
13	W2X11	26 25	19 23	73 3

FAD of a compressor should atleast be 85% of its rated capacity. When it falls below 85%, the reasons for deviation need to be examined and rectified It is recommended that a maintenance check of the above compressors be carried out for valve leakage, choked intake filters, worn out piston rings and worn out cylinder liners Appendix- 5/3 exhibits savings which may be expected from FAD improvement to 85% of the rated capacity Regular maintenance must be carried out to maintain the FAD capacities specified by the manufacturers

ii. Specific Power Consumption

The specific power consumption of an air compressor indicates it's power consumption for free air delivery of 100 m^3/h and is the most convenient way to measure compressor's energy efficiency. The specific power consumption depends on type of compressor, capacity, operating pressures, amount of free air delivered. The specific power consumption of all the compressors are estimated and the details are given in Appendix-5/4. For a double-stage compressor, the specific power consumption should be in the range of 8 5 - 11 5 For a single-stage compressor, it should be in the range of 6.0 - 8.0 The compressors having higher specific power consumption are tabulated below :

Sl. No.	Area	Compressor ID Code	Specific power consumption kW/(100 m^3/h)
1	Atox Mill	K2X20	14 41
2	Atox Mill	K2X21	14 71
3	Atox Mill	K2X23	15 66
4	Kiln - 2	W2X01	11 78
5	Kiln - 2	H2X02	15 07
6	Ph-1 Envirocare	W1X13 & W1X14	15 32
7	Ph-2 Envirocare	W2X13	12 84

Measures to improve FAD would also reduce specific power consumption

iii. Compressor Efficiency

All the compressors were studied for their efficiencies (which includes transmission efficiency also) Various parameters such as delivery pressure, actual FAD, power consumption were monitored The compressor efficiency calculations are given in Appendix - 5/5 The efficiency of a non-lubricated compressor is said to be satisfactory, if it is in the range of 60-70%

The compressors having efficiencies less than 60% are tabulated below:

Sl No	Area	Compressor ID Code	Compressor Efficiency, %
1	Atox Mill	K2U07	34
2	Atox Mill	K2U11	30
3	Atox Mill	K2X20	51
4	Atox Mill	K2X21	50
5	Atox Mill	K2X23	46

The improvement in FAD will also result in improved compressor efficiency

iv. Operating Parameters

Compressor operating pressures (loading & unloading), temperatures of air and water before inter-cooler and after-cooler, temperature of air and water after inter-cooler and after-cooler were monitored during the study These parameters are tabulated in Appendix - 5/6 The purpose of the inter-cooler is to reduce the temperature of the compressed air, there-by it's volume and hence, reduce the work required to compress it in the next stage Ideally the air should be cooled to it's I - stage intake temperature. Increase in air temperature after inter-cooler due to scale formation, etc., will increase the specific power consumption of the compressor Every 4°C rise in air temperature would result in 1% higher power consumption in the subsequent stages

The compressors having air temperature above 40°C after the inter-cooler are tabulated below

Sl No	Area	Compressor ID Code	Temperature of air at outlet of Inter-cooler
1	Cement Mill - 4	Z4U07	38,50
2	Cement Mill - 4	Z4U08	41,55
3	Cement Mill - 4	Z4U11	45,38
4	Atox Mill	K2X21	42
5	Atox Mill	K2X23	44
6	Kiln - 1	W2X10	45

Hence de-scaling of inter-coolers has to be carried out for the above compressors which will reduce the air inlet temperature for the second stage and reduce the energy consumption.

The after-coolers are meant for reducing the storage volume required for the compressed air by reducing it's temperature. The compressors having air temperature above 40°C after the after-cooler are tabulated below

Sl No	Area	Compressor ID Code	Temperature of air at outlet of After-cooler
1	Packing House	P2X10	47
2	Packing House	P2X11	56
3	Packing House	P2X12	45
4	Atox Mill	K2U07	45
5	Atox Mill	K2U11	43

De-scaling of after-coolers for the above compressors should be carried out to reduce the air storage volume requirement Also it was observed that the compressors in cement mill-4 don't have after coolers

v. Loading Pattern of Compressors

The compressor loading and unloading time (cycle time) were noted to calculate the percentage loading duration of the compressors. The details are given in Appendix - 5/7 The percentage loading duration of W2X10 compressor, under normal operation, was observed to be 74%. But it was found to be 90 7%, when the compressed air was also used for body cleaning This kind of compressed air wastages should not be allowed since, a 5 mm opening in compressed air line could result in a loss of about 1 5 m^3/min at 6 kg/cm^2(g) pressure A separate blower could be provided for the body cleaning purpose. During the study W2X14 screw compressor was found to be running in unloaded condition continuously, although it was claimed that automatic switch-off has been arranged The proper working of such automatic systems should be checked.

vi. Compressed Air Utilisation Pattern

The user list of compressed air along with their rated consumption and pressure for all the compressors are given in the Appendix-5/8 The actual pressure and quantity of compressed air required at the user point were compared with those at the generation point Replacement of compressor by blower for low pressure requirements was also studied They are discussed in detail in the following sections.

vii. Operating Only Two Low Pressure Compressors And Reducing The Pressure Setting To 1.2 kg/cm^2 (g) in the Packing Plant Area

Normally in packing house, three low pressure compressors delivering air at 2 2 kg/cm^2 (g) are operated for silo and packer aeration, when 8 packers are operated The FAD of the compressors were found to be less than 85% By improving the FAD to 85% of the rated capacity and arresting all the body cleaning tapping points, it is possible to stop one of the compressors

Moreover, the pressure at the user point was physically measured and found to be 1.0 kg/cm^2 (g). Hence, the delivery pressure at the generation point can be reset to 1.2 kg/cm^2 (g). The savings that can be achieved by implementing the above measures are worked out in Appendix - 5/9

viii. Optimisation Of Compressed Air Usage In Cement Mill Area

The cement mill was initially designed for pneumatic conveying of cement from cement mill to silos through fluxo pump. Presently, for three cement mills pipe conveyor is in operation for conveying cement to silos and for cement mill - IV, whenever Special Grade Cement is manufactured, pneumatic conveying is used

All the compressors used presently are designed for pneumatic conveying By optimising compressed air usage and replacing two high pressure compressors with one low pressure compressor and one lower capacity high pressure compressor, the specific power consumption can be brought down Savings that can be achieved by this measure is given in Appendix-5/10

ix. Operating Only Two High Pressure Compressors in Atox Mill Area

Presently three high pressure compressors (K2X20, K2X21, K2X22) are operated in Atox Mill section to meet the compressed air requirements of filters and pneumatic gates The FAD of the compressors are respectively, 60 5%, 59 2% and 57.6% By improving the FAD to 85% and arresting all the body cleaning tapping points, it could be seen that two compressors are sufficient to meet the demand Hence, one of the compressors can be switched-off The details are given in the Appendix - 5/11

x. Use of Blower Air Instead of Compressed Air for Coal Conveying

At present compressed air at 0 8 kg/cm^2 (g) is used to convey the pulverised coal to storage bin through C P Pump. For low pressure applications (upto 1 kg/cm^2 (g)) like this, a blower can be used, which will have lower specific power consumption compared to compressors. The calculation details are given in Appendix- 5/12

xi. Replacing V-Belts of Compressor Motors with Flat Belts

Presently, except few compressors, all are using V-belts for power transmission V-belts cause power loss of about 3% of the belt power rating and 1% of the absorbed power due to wedging-in & wedging-out action, windage and creep These V-belts can be replaced with synthetic flat belts, which could be designed for nil power loss and 99% transmission efficiency The power savings by incorporating this measure would be in the range of 5-6% of the absorbed power. The detailed calculations are given in the Appendix-5/13

xii. Performance of Instrumentation in Compressed Air System

The instrumentation for entire compressed air system was studied The instruments necessary for compressed air systems are discussed in chapter-10 The observations regarding performance of Compressed air system in the entire plant is discussed (department wise) below·

Sl. No.	Area	Compressor Code	Observations
1	PACKING PLANT	P2X14, P2X15 & P2X16	Pressure gauges at Compressor are working satisfactorily, in both the stages and Air receiver temp Gauges for Air & water (inlet & outlet) before & after inter cooler are not available
		P2X10, P2X11 & P2X13	The pressure gauges at compressors are to be calibrated since the pressure readings are different from Air receiver The pressure gauge in air receiver is working satisfactorily Temp Gauges for air & water are not available
2	CEMENT MILL	Z3U09	Pressure gauges at compressor & Air receiver working satisfactorily Temp Gauges not available
		Z4U07	Pressure gauges at compressor point not working satisfactorily, temp Gauges not available
		Z4U08	Pressure gauges at compressor point working satisfactorily Temp Gauges not available
		Z4U09	Pressure gauges at compressor point not working satisfactorily, temp Gauges not available
		Z4U11	Pressure gauges at compressor point working satisfactorily Temp Gauges not available
			In cement mill area for most of the compressors, the pressure gauge at I stage was not functioning
3	ATOX MILL AREA	K2U07, K2U11	Pressure gauges are found to be working properly
		K2X20, K2X21, K2X23	Pressure gauges are working properly
			Pressure gauge need to be calibrated temp Gauges not working The receiver gauge also need to be calibrated, as the reading shown It is different from compressor discharging
4	KILN-I	W2X08, W2X10	Receiver pressure gauge need to be calibrated Temp Gauges are not working properly
5	KILN-II	W2X01, H2X02	Receiver pressure gauge is not working properly Temp Gauges are not working
		H2X01	Temp Gauges are not working properly
6	PHASE-II ENVIROCARE	W1X12, W1X 13, W1X 15	Pressure gauges are not working properly Ammeters are not working properly
7	PHASE-II ENVIROCARE	W2X11,13	Pressure gauges are not working properly, Ammeter are not working properly

6.3 RECOMMENDATIONS

A. Improving Compressor FAD

The Atox mill area compressors K2U07, K2U11, Kiln 1-area compressor W2X10, Kiln 2-area compressor H2X02 and Envirocare compressors W1X12, W1X13, W1X14, W2X11 operate with lower FADs. The FAD of compressors should atleast be 85% By proper maintenance, the FAD of these compressors could be improved above 85% Refer section 5 2.(i) for details

Estimated savings :

Total power savings	= 119 kW
Annual energy savings	= 4 46 lakh kWh
Annual cost saving	= Rs 13 38 lakhs
Investment required	= Rs 3 50 lakhs
Simple payback period	= 4 months

B. Operating Only Two Low Pressure Compressors And Reducing the Pressure Setting To 1.2 Kg/cm^2 (G) In The Packing Plant Area

In packing house, 3 LP compressors are operated, supplying air at 2 2 kg/cm^2 (g) for silo and packer aeration The FAD of these compressors are less than 85% By improving the FAD to 85%, one compressor can be switched-off Moreover, as the pressure required at the user point is only 1 0 kg/cm^2 (g), the delivery air pressure at the compressor can be reset to 1 2 kg/cm^2 (g) Refer section 5 2 (vii) for details

Estimated savings :

Total power savings	= 127.8 kW
Annual energy savings	= 5 68 lakh kWh
Annual cost saving	= Rs 17.03 lakhs
Investment required	= Rs 2 00 lakhs
Simple payback period	= 2 months

C. Optimisation of Compressed Air Usage In Cement Mill Area

Pipe conveyor is used for conveying cement from cement mill to silo for cement mill - I to III and whenever Special Grade Cement is manufactured in cement mill - IV, for which pneumatic conveying is used All the compressors in this area are designed for pneumatic conveying By optimising compressed air quantity and replacing two high pressure compressors with one low pressure compressor and one lower capacity high pressure compressor, the specific power consumption can be reduced Refer section 5 2 (viii) for details

Estimated savings :

Total power savings	= 183 kW
Annual energy savings	= 14 49 lakh kWh
Annual cost saving	= Rs 43 48 lakhs
Investment required	= Rs 29.00 lakhs
Simple payback period	= 8 months

D. Operating Only Two High Pressure Compressors in Atox Mill Area

By improving the FADs of Atox mill area compressors K2U20, K2U21, K2U23 to 85%, it is possible to switch-off one of the compressors as the air delivered from the other two would be sufficient to meet the demand. Refer section 5 2.(ix) for details

Estimated savings :

Power savings	= 36 kW
Annual energy savings	= 2 83 lakh kWh
Annual cost saving	= Rs.8.48 lakhs
Investment required	= Rs 2 00 lakhs
Simple payback period	= 3 months

E. Use of Blower Air Instead of Compressed Air For Coal Conveying To Storage Bin In Atox Mill Area

In Atox mill section, compressed air at 0.8 kg/cm^2 (g) is used for conveying pulverised coal to the storage bin Blowers can be used for such low pressure applications as they have lower specific power consumption compared to air compressors Refer section 5.2.(x) for details

Estimated savings :

Net power savings	= 13 kW
Annual energy savings	= 77220 kWh
Annual cost saving	= Rs 2.32 lakhs
Investment required	= Rs.2 00 lakhs
Simple payback period	= 11 months

F. Replacing V-Belts of Compressor Motors with Flat Belts

V-belts used for power transmission in compressors can be replaced with flat belts, as V-belts cause power loss of about 5-10% of the absorbed power. Refer section 5 2 (xi) for details

Estimated savings :

Total power savings	= 32 kW
Annual energy savings	= 2.44 lakh kWh
Annual cost saving	= Rs 7 32 lakhs
Investment required	= Rs 1 91 lakhs
Simple payback period	= 3 months

SUMMARY OF POTENTIAL SAVINGS

Sl. No.	Proposal	Annual Savings Potential		Cost of implementation, Rs lakh	Simple payback penod, months
		lakh kWh	Rs lakh		
1	Improving Compressor FAD	4 46	13 38	3 50	4
2	Operating Only Two Low Pressure Compressors And Reducing The Pressure Setting To 1 2 kg/cm2 (g) In The Packing Plant Area	5 68	17 03	2 00	2
3	Optimisation Of Compressed Air Usage In Cement Mill Area	14 49	43 48	29 00	8
4	Operating Only Two High Pressure Compressors in Atox Mill Area	2 83	8 48	2 00	3
5	Use of Blower Air Instead Of Compressed Air For Coal Conveying To Storage Bin In Atox Mill Section	0 77	2 32	2 00	11
6	Replacing V-Belts of Compressor Motors with Flat Belts	2 44	7 32	1 91	3
Total		**30 67**	**92.01**	**40.41**	**6**

ELECTRIC DRIVES

FACILITY DESCRIPTION

Electric drives contribute to the lions share of electricity consumption in L&T ACW They are used for various applications such as :

- Fans
- Blowers
- Pumps
- Ball Mills
- Crushers
- Conveyor
- Material Handling Equipments
- Compressors

Electric drives in ACW comprise of both H T. motors with operating voltage of 6 6 kV and L T motors with operating voltage at 415 volts. The plant has come up in 2 phases Phase - I in 1983 and Phase - II in 1987 and subsequently both the phases have been upgraded in the year 1994 Majority of the L T motors presently used are squirrel cage induction motors in DOLL starting mode and for some of the major application, H T slip ring induction motors with L R S./G R S. have been used Besides above D C motors for main kiln drive have been used for both the phases

The connected motor loads are as given below :

Locations	Connected Motor Load in kW	
	6 6 kV	415 Volts
Phase - I	14,030	8588.67
Phase - II	12,780	8380.87
Cement Mill	15,200	4767.81
Packing Plant	-	2658.58
Mines & Coal Crusher	3,960	2222 82
Sub-Total	45,970	26618 75
Total	72588.75	

The range of motor capacity spans over 0 37 kW to 225 kW for L.T motors and 200 kW to 5400 kW for H T. motors.

The study has been conducted by carrying out on-line measurements of power parameters for the drives rated above 11 kW and few sample measurements of lower rating motors The application details have been studied and discussed jointly with plant management Suitable recommendations for energy efficient measures have been proposed and discussed

6.2 OBSERVATIONS, ANALYSIS AND FINDINGS

The instantaneous power parameters e g volts, amps, p f kVA and kW have been measured with the help of portable load analyser for H T motors and clip-on power meters for L T motors In selected application areas, continuous monitoring over a period of time is carried out These datas have been used for analysis and conclusion

6.2.1 H.T. MOTORS

Motor Loading Parameters

The power parameters as measured are presented in Appendix - 6/1. It is observed that the HT motors are generally loaded 85% and above in Phase - I except for fans The operating p f is 0.80 - 0 95.

In Phase - II similar loading pattern exists with better average p f. of 0 87 and above

However, in Cement mills HT motors are loaded more than 93% with p.f. of 0 81 - 0 95

A. PHASE - I :

The raw mill main motor (3000 kW) R1MO3 is loaded between 83 to 94% with p f of 0 83 whereas R1M23 is loaded around 87.3 % Both these motors are with L R S starting method and normally operates at more than 90% load continuously throughout the day.

The Envirocare compressor is loaded between 71 5 to 94 5% with p f. less than 0 8 The compressors W1X11 to W1X14 which are in use for GCT water spray have been normally loaded upto 90 % or above.

The coal mill motor K1MO3 (950 kW) is loaded at 86 9% with p.f. of 0 98. However the Phase - I coal mill is not as efficient as ATOX mill in Phase - II

The raw mill fan R1PO5M1 (700 kW) is found to be loaded around 58% with p f of 0 92

Whereas the rotary separator (315 kW) motors is loaded optimally around 95.2% with p f. of 0.85.

The cooler fans W1K16M1 and W1K17M1 are with variable speed L.R S. feature and are loaded between 38 8% to 67 8% with p.f. > 0.9.

The cooler ESP fan W1P51 (425 kW) is loaded around 67.5% with p.f. of 0.86 The load being variable in nature, the plant has already used slip power recovery system for above fan

Similar measure is also adopted for kiln ESP fan J1P44 (600 kW) which is loaded around 85% with p f of 0 86.

The smoke gas fans J1J01 / J1JO3 (1650/950 kW) are loaded 89 9% and 99 9% respectively with p.f of operation around 0 90 Both these fans are with V S L R S feature and their speed depends on the kiln feed rate and corresponding damper opening

The energy efficiency study of fans is dealt in Chapter No 4

From the observed parameters as discussed above it is found that in Phase - I, most of the H T drives are loaded more than 80% and various energy saving measures along with measures for p.f improvement are already in existence

B. PHASE - II

The raw mill main motor R2MO3 (5400 kW) is loaded around 81 9% with p f around 0 90 Normally the requirement of speed variation is absent for this application And L R S is used for starting purpose

The raw mill separator R2S01 (325 kW) is loaded around 62.5% with low p f of 0 56

The raw mill fan R2P05 (825 kW) which is connected with energy saving S.P R S device is loaded only 48 6% with p.f. of operation only 0.67.

The coal mill motor K2M03 (680 kW) is loaded around 75% with p f. of 0.93 This mill is ATOX mill (i e. vertical roller crusher) with better energy efficiency as compared to Phase - I.

The coal mill fan K2701 (600 kW) is loaded in varying degree (83.7% to 102 5%) with p f ranging between 0 87 - 0 88

The screw compressors W2X11 to W2X13 of 200 kW ratings are loaded between 62% to 97% with p f ranging between 0.78 - 0.90.

The cooler ESP fan W2P31 (600 kW) is loaded only by 33.7% with p f. of 0 77 However due to variable speed requirement, the plant is using S P R S towards energy savings.

The kiln ESP fan J2P09 is with variable speed grid resistance control start and loaded 84 %

The smoke gas fans J2J01 and J2J03 are loaded 92 7 % and 85 6 % respectively and with p f of operation varying between 0 87 to 0 90 These fans are fitted with V S L R S / V.S G R S.

Therefore in Phase - II for the H T drives, with variable torque / speed application, the plant management has already adopted suitable energy saving measures

C. MINES

Limestone from quarry is crushed at old crusher house and at new crusher house The old crusher house is located close to Phase - II with primary and secondary crusher drives of 760 kW and 1000 kW respectively. The new crusher house located at L S. mines has primary and secondary crusher drives of 1000 kW and 1200 kW respectively. The crusher loading was observed to be a continuous shock load The 3ϕ microprocessor based power analyser was used to monitor the operating load of crusher 6 6 kV HT motors. The details are given in Appendix - 6/1

The old crusher is used sparingly, mainly in the event of breakdown or maintenance of the new crusher The new crusher at mines will be under operation for more than 7000 hours in a year

The loading parameters of motors coupled to new crusher is around 80% The instantaneous load variations are high Due to non uniform nature of sizes and hardness of limestone from quarry, the crusher requires such deration for smooth functioning and withstanding short time peaks and temperature rise of motor windings As such there is no potential for energy savings with the drives coupled to crushers

D. CEMENT MILL

The cement mill 1 is driven by two motors Z1M03 and Z1M23 of 1800 kW each which are loaded between 93 2 - 94 8% with p f of 0 86 - 0 95

The cement mill 2 is driven similarly by two motors Z2M03 and Z2M23 loaded around 96 - 97% with p f varying between 0 86 - 0 95.

The cement mill 3 Z3MO3 (4000 kW) is loaded around 98% with p.f. of operation as 0 81.

All the above 3 cement mills are used for OPC - 53 grade cement and with LRS starting system They are normally operating 24 hours a day and with constant nature of load

The cement mill No 4 Z4M03 (4000 kW) is used for the special grade of cement presently and being loaded 95 4% with p f of 0 95

Because of their optimum loading and constant nature of torque/speed requirement, no scope arises for adopting measures towards energy conservation except for required reactive compensation which is partly in existence

6.2.2 L.T. MOTORS

The power parameters for various L T drives have been tabulated in sectionwise as below

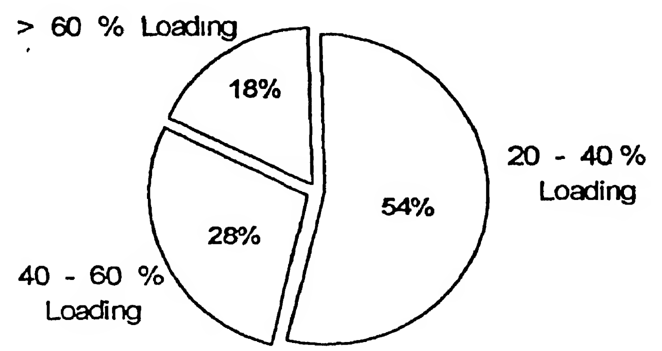
a	Phase - I .	(Appendix - 6/2)
b	Phase - II . . .	(Appendix - 6/3)
c	Old L S Crusher, New L S Crusher & Coal Crusher .	(Appendix - 6/4)
d	Cement mill and Pump House . . .	(Appendix - 6/5)
e	Packing plant . .	(Appendix - 6/6)

A. PHASE - I

L T drives are being used for varied application such as Hydraulic pump, material handling equipment, conveyors, dust filter fans, hammer mill, cooler fans, F K /C P. Pump blowers

The Pie graph below represents the percentage loading of LT motors in Phase -I. It is observed that around 54% of motors are found operating in the loading range of 20 - 40% Around 28% of motors are loaded in the range 40 - 60% Majority of L.T motors are being operated at a voltage level of 419 - 421 volts.

PHASE # I LT MOTOR % LOADING



Number of motors operating at loading below 40%, even to the tune of 20% or below are observed with a low p f. varying from 0 22 - 0 59 Particularly the bucket elevator R1J01M1 (110 kW) is loaded around 17 2% and the hammer mill W1M01 (160 kW) is loaded around 11 4% with very low p f 0 51 and 0 29 respectively

The screw conveyors J1U41M1 to J1U43M2 are loaded poorly below 15% with an average p f around 0 3

It is observed that the cooling fans W1K10 - W1K15 (225 kW) are operated with variable speed depending on the operating conditions, kiln feed etc This has contributed to substantial energy savings and comparatively improved p f. in the range of 0.81 - 0 87.

The motors which are operating with very low loading and poor p f. if operated in `STAR' mode shall contribute to better loading pattern with improved p f of operation. However, it is necessary to check the driven load requirement before shifting to `STAR' mode. The use of Auto DELTA - STAR controller can facilitate such application.

The hammer mill motor is grossly overrated for its application demand. However, the plant management expressed that for avoiding trippings due to sharp peak overload, use of such higher capacity is being continued. The operation also got a continuous fluctuation and kick loads.

It is proposed that use of suitable electronic starter with energy savers shall help in maintaining smooth operation and higher p f. of operation. This will also facilitate less wear and tear in the mechanical parts

Some of the motors, which are operating at a loading of 40-60% are observed to have higher p f of operation between 0 61 - 0.85.

The Coal mill fan K1U43 and K1U45 (150 kW) are coupled to slip ring motors

The primary air fan W1V07 (110 kW) can be retrofitted with variable speed drives for better energy efficiency or can be replaced with high efficiency fan

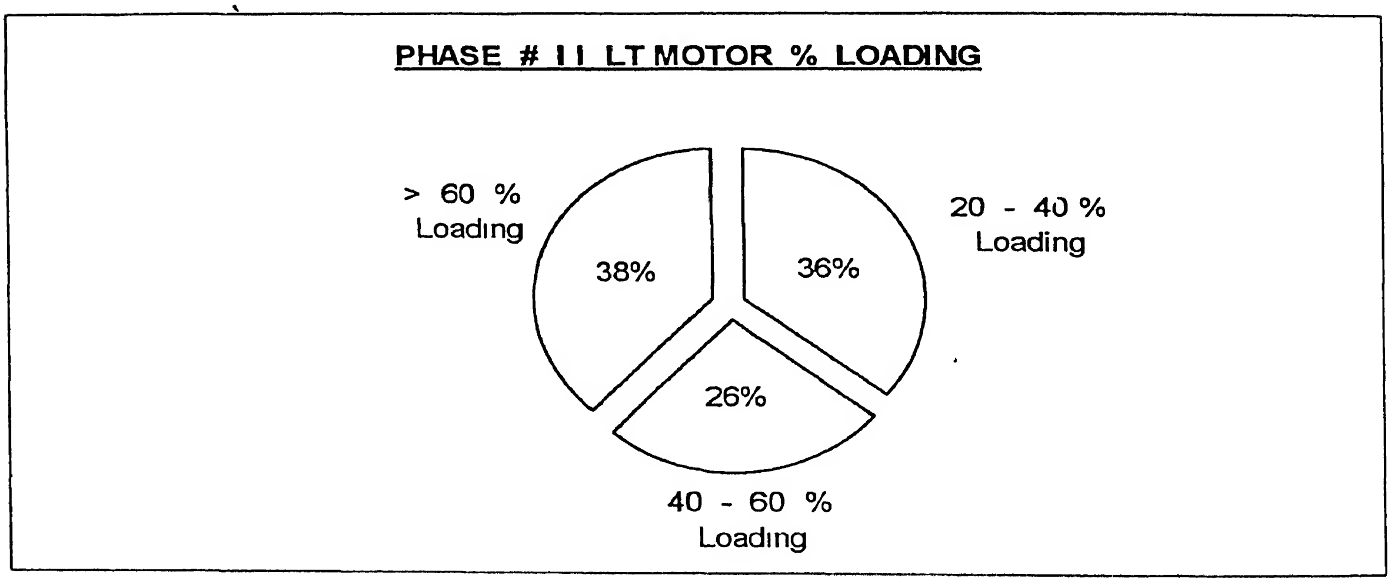
Besides above, from the observed loading parameters it can be concluded that there lies a scope of optimum sizing of motors for number of applications

A few motors are observed to be loaded beyond 60% with p.f. of operation between 0.73 - 0 85.

It is observed that in Phase - I mostly standard motors are in use.

B. PHASE - II

In Phase - II, the number of motors operating under different load condition is presented in Pie graph as below :



From the Pie graph above it can be seen that around 36% of motors are found loaded in the range 20 - 40% About 38% of motors are found operating above 60% loading range

In Phase - II also similar condition persists for hammer mill W2M01 (190 kW) which is hardly loaded around 8 2% with poor p f. of 0.45

The cooler fan W2K10 - W2K17 are presently operated on DOL mode. However recently variable speed drives have been installed for energy efficiency improvement. It is proposed to be commissioned within 1 or 2 months Similarly the Dynamic separator K2P74 (90 kW) is observed to be loaded by 24 7% with p f. 0 92 due to its VSD feature.

In Phase - II, though number of motors are found to be operating between 40 - 60% loading, their operating p f is observed to be higher (0.59 - 0 82) as compared to Phase - I This is due to use of high efficiency motors in Phase - II It is also observed that the loading % is better in Phase - II comparatively And a number of motors are existing with high starting torque feature particularly of NGEF make.

The fans and blowers are dealt mainly in Chapter - 4 0

The water pumps R2X50 and R2X52 (both 30 kW) are found to be loaded at 77% and 100% respectively with p.f of 0 78 - 0.85. In both the cases the outlet is throttled by 70-80% It was discussed with plant personnel and understood that there is a proposal for use of high efficiency pump to bring down energy usage

The manufacturing process being dry, the cooling water requirement is less The pumps are mainly used to pump cooling water to the Gas conditioning tower, Compressor, Gear boxes, Cement mills etc.

C. COAL CRUSHER AND L.S. MINES

The Coal primary and secondary crushers are observed to be loaded very low But due to its nature of load the sizing is not feasible

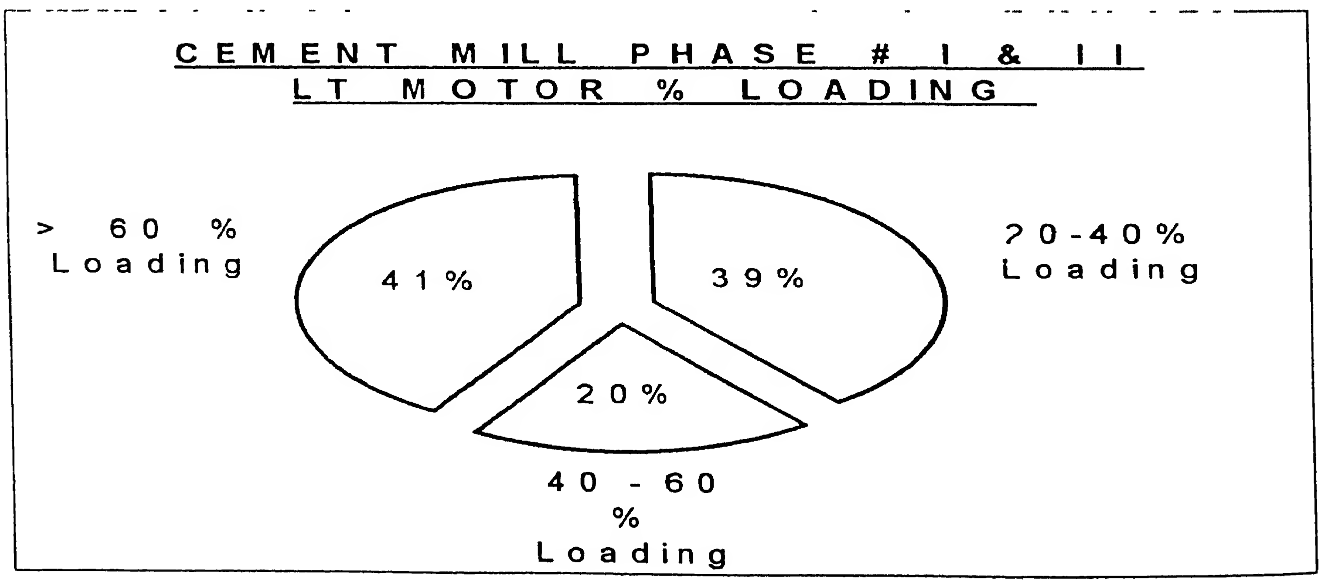
The RBC's are found to be loaded between 45 to 49% with p.f. around 0.75 The primary and secondary chain reclaimer are loaded 31.5% and 28.5% respectively The dust filter fan A0P04 (75 kW) is operating at a load of 77.2% with p f. 0.71.

In limestone mines, the conveyor belts A3J04M1 - M3 (II 90 kW) are subjected to surge load and hence fitted with fluid coupling system. They are loaded 64% to 82% with p f of 0 70 - 0 77 Plant has also initiated measure to stop idle running of such conveyors

The dust filter fan is loaded around 55% with p.f. 0 75 It is a constant speed requirement

D. CEMENT MILL AND PUMP HOUSE

Number of motors operating under different loading patterns is represented in the Pie graph below



From the Pie graph it can be seen that around 39% of motors fall in the range of 20 - 40% loading About 41% of motors are found operating above 60% loading range

The compressors in cement mill Z1U11 and Z1U13 (160 kW) are optimally loaded around 95 35 to 100% with p f 0 89 - 0.90 under load condition and 22-25% with p f. 0 60 - 0 65 under no load condition The time for loading / unloading is almost equal Some of the compressors are found to be flat belt driven which helps in lesser friction loss

The new ESP fan Z2P07 (110 kW) is loaded by 61% with p f 0.75 while being operated at 80% damper open condition.

The separator fan Z2S23 (200 kW) is with fixed speed GRS system and currently loaded upto 69% with p f 0 68.

The filter fans and dedusting filter fans are operating at less than 25% loading with poor p f

The bucket elevator system introduced for energy conservation are loaded around 34 8 to 46 4% with p f ranging from 0 64 - 0 80 The variable load and high starting torque demand necessitates extra capacity of the bucket elevator motors

In Pump House, most of the pumps are rated for 30 kW except for pump No 5 which is 11 kW The pumps are operating at loading range 74 to 92% with p f 0 72 to 0 84

The return pumps are loaded around 49% to 52% with p.f. of 0.70.

In Cement mill it is observed that number of under-loaded motors are contributing to low p f These can be taken up for STAR operation subject to compliance of starting torque requirement

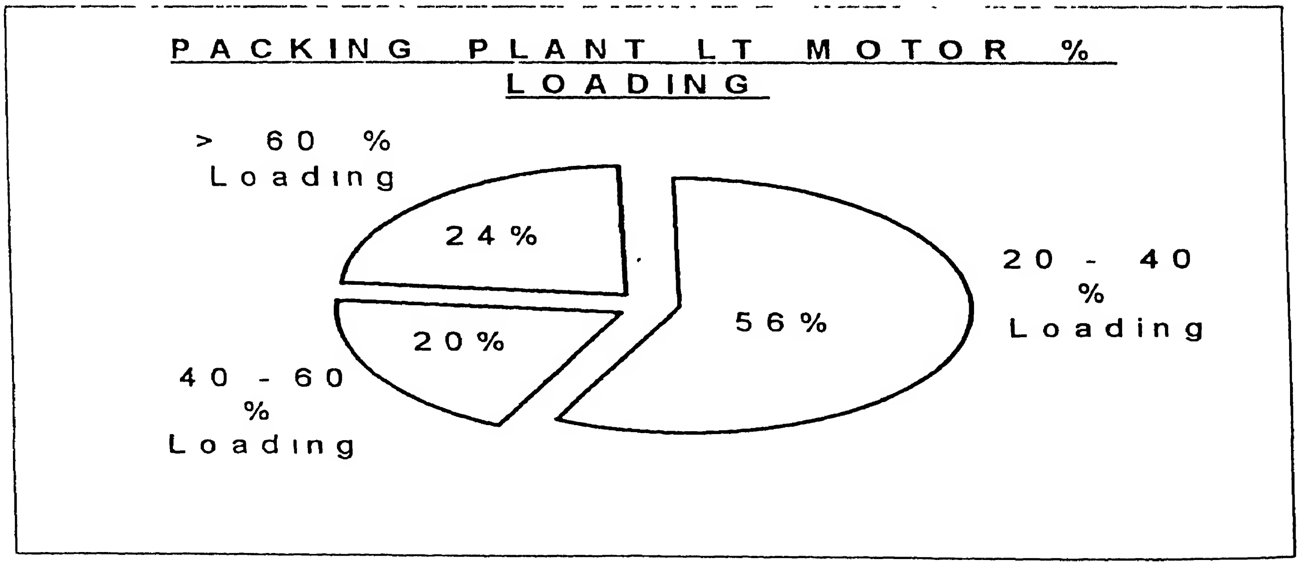
E. PACKING PLANT

In packing plant major loads are compressors, which are dealt in detail in Chapter No 5

The compressor motors are loaded between 67 - 72% with p f. 0.7 to 0 84

The bucket elevators are loaded partly whereas the jet pulse filter fans are loaded close to 70% with p f 0 75 on an average

Around 56 % of Packing Plant Motors are observed to be operating under 20 - 40% loading range, as represented in the Pie graph below.



6.3 RECOMMENDATIONS

A. General

a Though the plant is having well structured information on drives, it is suggested that for all important drives, suitable history cards be maintained for future reference. This will also help the management to assess the suitability of each motor to its application and to take decisions regarding replacement / rewinding

b The plant being under continuous operation, preventive routine check on crucial drives shall help in reducing down time.

c Necessary precaution during rewinding of motors should be taken.

d In feasible cases, motor terminal based reactive compensation shall help in avoiding distribution loss.

B. Star Mode Operation of Under-loaded Motors

The motors with active loading less than 35 - 40% may be run in `STAR' mode This will reduce the energy consumption and simultaneously improve the p f of operation because of reduced iron losses. However it is necessary to comply with the starting torque requirement. A number of motors in various areas are identified to be operated in `STAR' mode and the results of calculated energy savings are tabulated in Appendix - 6/7

This will result in annual energy savings to the tune of 68793 kWh.

Annual energy savings	=	68793 kWh
Cost of annual energy savings	=	Rs.2 63 Lakhs
Cost of implementation	=	Nil
Simple payback period	=	Nil

A number of motors are identified which are usually loaded in the range of 35 - 40 % . They are seldom operated above 50% loading as per process demands Adoption of Auto DELTA - STAR controllers (Operates in Star mode when the motor is under-loaded and changes over to Delta mode when motor load exceeds 40%) for these motors, yield energy savings as tabulated in Appendix - 6/8 This will result in annual energy savings to the tune of 101658 kWh.

Annual energy savings	=	101658 kWh
Cost of annual energy savings	=	Rs.3 05 Lakhs
Cost of implementation	=	Rs 2 72 Lakhs
Simple payback period	=	0 89 years

C. Optimum Sizing and Use of Energy Efficient Motors

From the foregoing study, it is observed that in Phase - I number of motors are grossly under-loaded and also operating at low p.f whereas for similar condition of loading in Phase - II, drives are operating at better level of p f. This is directly the reflection of standard motors in use in Phase - I

Therefore optimum sizing and use of energy efficient motors shall assist in

i Optimum use of energy and motor capacity.

ii Improved operating efficiency.

iii Reduced magnetic loss thereby resulting in cooler operation of motor.

iv Improved p f of operation (i e reduced maximum demand / kVAr demand)

Number of application areas have been looked into detail for suitability of sizing and use of energy efficient motors The workout and tabulation is given in Appendix - 6/9

The annual energy savings achievable by adopting this proposal are as follows .

Annual energy savings	=	663420 kWh
Cost of annual energy savings	=	Rs 19.9 Lakhs
Cost of implementation	=	Rs 26 63 Lakhs
Simple payback period	=	1 34 years

D. Energy Savings by Use of Electronic Energy Savers

The motors coupled to drives such as hammer mill, hydraulic pump, etc , are proposed to be connected with electronic energy saver. This will result in following benefits

* Improved P F of operation of motors at all varying load cycles (upto 0 90)

* Reduced starting surge by way of sampling the voltage waveform

* Energy savings due to reduction in magnetic losses.

* Minimise mechanical wear and tear of drive and driven parts.

* Reduced heating of motor (improved operating efficiency)

* Improved P.F (reduced kVAr demand on system).

The best option to minimise maximum demand drawal from SEB with electric drives operating at low P.F , is by use of electronic power factor control drive

A sample calculation of results are tabulated along with other results in Appendix - 6/10a & 6/10b The maximum demand reduction due to P F control drive or softstart has been taken at 50% of compute kVA savings

The annual energy savings possible by implementing this measure are as follows ·

Annual energy savings	=	30486 kWh
		(210 kVA of Max demand) *
Cost of annual energy savings	=	Rs 2 80 Lakhs *
Cost of implementation	=	Rs.5 03 Lakhs
Simple payback period	=	1 8 years

* 50 % of kVA MD savings taken for techno-economic computation

SUMMARY OF POTENTIAL SAVINGS

Sl No.	Recommendations	Annual Energy Savings		Investment requirement	Simple Payback period
		kWh	Rs. in Lakhs	Rs. in Lakhs	Year
1	Star mode of operation	68793	2 63	-	Nil
2	Auto -Delta -Star mode of operation	101658	3.05	2.72	0.89
3.	Energy Efficient motors	663420	19 90	26.63	1.31
4.	Electronic Energy Savers	30486	2.80	5.03	1.8
Total		**864357**	**28.38**	**34.38**	**1.21**

7.0 REFRIGERATION / AIR CONDITIONING & CANTEEN SYSTEMS

7.1 REFRIGERATION / AIR CONDITIONING SYSTEMS

7.1.1 FACILITY DESCRIPTION

The refrigeration system consists of 7 chilled water systems, 4 direct expansion systems and 3 slimline systems apart from window air conditioning systems Refrigeration systems with capacities exceeding 10 TR had been taken up for study. All the systems run with R-22 as refrigerant The capacity details and respective usage areas of the units studied have been tabulated below The various design parameters of refrigeration machines and chilled water pumps are given in Appendix - 7/1

Sl No	Location	Make & Type of units	No of Units	Rated TR	Usage Areas
1	CCR-Bldg	VOLTAS-Chilled Water System	3	40	* II Floor - CCR * II Floor - PLC * Ground Flr - PLC * Kiln Feed - PLC * Raw Mill - PLC * Coal Mill - PLC * SPRS Room
2	CCR-Bldg	VOLTAS-Chilled Water System	1	40	* I Floor - Office
3	ADM-Bldg	VOLTAS-Chilled Water System	1	40	* Ground Floor, - Personal * GroundFloor, - Conference Hall * I - Floor, Purchase * I - Floor, Accounts
4	ADM-Bldg	VOLTAS-Chilled Water System	2	20	

7.1.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Loading Pattern of Compressor and Pump Motors

The loading pattern of motors of compressors, pumps, etc. have been discussed separately in Chapter-6

B. Machine Side Parameters of Various Refrigeration Units

Following parameters pertaining to the operation of refrigeration systems were measured

i. Compressor

* Suction and discharge pressures and temperatures

ii. Chiller

* Chilled water inlet and outlet pressures and temperatures

iii. Condenser

* Cooling water Inlet and outlet pressures and temperatures.

The observations on machine side parameters of all the refrigeration units under operation are tabulated in Appendix - 7/2

The compressor suction and discharge pressures and temperatures were found to be within allowable limits except for ADM-M/c.1 which had low discharge pressure. The chiller/condenser side parameters are discussed in section D

It was observed that majority of pressure and temperature gauges were not working properly By installing new gauges, periodic maintenance can be easily planned by the operating personnel.

C. Performance Evaluation

The determination of actual tonnage of refrigeration generated needs measurement of chilled water flow and temperature drop across the chiller. As the M/c 2 & M/c 3 have common chilled water lines, they were studied together Calculation details of actual TR generation of the machines studied are given in Appendix-7/3 The results are tabulated below

Sl No	Particulars	Rated TR	No of Cylinders in Operation	Actual TR
1	CCR - M/c 1	40	3	35 6
2	CCR - M/c .2	40	3	73 7
3	CCR - M/c 4	40	4	
4	ADM -M/c 1	40	4	26 5

The TR generation of CCR-M/c 1 and CCR-M/c 2 & 3 together were found to be satisfactory However, the TR generation of ADM-M/c.1 was found to be as low as 66 3 % Lower compression ratio of the ADM - M/c 1 compressor was one of the reasons for its lower TR generation.

D. Evaporator and Condenser Effectiveness

The observed temperature and pressure drops across evaporators and condensers are given in Appendix -7/4 The acceptable range of pressure drop is 0 5 - 0 8 kg/cm^2 However, the evaporator pressure drop in CCR-M/c.1 and condenser pressure drop in ADM-M/c 1 were found to be 1 kg/cm^2 This could lead to lower refrigerating effect in the evaporator.

It is advisable to have cleaning schedule of the evaporators and condensers based on pressure drop rather than the presently followed one based on time

E. Distribution System

The distribution network of chilled water in the CCR and ADM buildings were observed to be satisfactory However, the cold insulation of supply and return lines of PLCs outside the CCR building need to be improved

F. User Load Assessment

Assessment of chilled water loads has been carried out for all the major user areas in both CCR-plant and ADM-plant systems. User-wise measured loads and measured air flows vis-a-vis design air flow of air handling units have been tabulated below Calculation details are given in Appendix - 7/5

Sl No	Location	Rated Air Flow	Actual Air Flow	% Air Flow	Rated Refrig. load of AHU	Total Refrig. load of AHU
		cfm	cfm		TR	TR
	CCR Bldg - Plant					
1	I - Flr	22500	16225	72 1	33 0	30 35
2	II - Flr, CCR	7500	7232	96 4	11 5	6 12*
3	II - Flr, PLC	7500	7350	98 0	13 3	7 29*
4	Ground Flr, PLC	22500	10860	48 3	12 5	5 29*
	ADM Bldg - Plant					
5	Ground Flr, Personal	7500	5508	73 4	-	6 30
6	Ground Flr, Conference Hall	7500	5352	71 4	-	7.07
7	I - Flr, Purchase	7500	6354	84 7	-	7 06
8	I - Flr, Accounts	7500	6438	85 8	-	6 30

* The lower AHU -TR can be due to the partially closed louvers in the distribution lines of usage areas

G. General Recommendations

I) During the study it was observed that some of the nozzles had been removed from the cooling tower spray header, while some of the remaining nozzles got choked. This reduces the effectiveness of the cooling tower and subsequently the efficiency of the water cooled utilities.

II) Use of AIR CURTAINS is proposed for the doors which are frequently opened and closed (eg. ADM building front door, Central Control Room)

III) The direct sun light entering through ADM building rear side adds to the heat load of the refrigeration unit Means of reducing this heat load like providing few more sun light control sheets should be done.

IV) At present, ordinary drinking water is used for chilled water make up This leads to the scale formation inside the evaporator and chilled water lines, reducing the heat transfer Hence, treated water should be used for chilled water make up.

V) Openings in the conditioned rooms (mainly in PLC room floors and not fully closed doors) leads to escape of conditioned air. Measures should be taken up to avoid such losses

VI) Presently the cooling water coming out from CCR-plant room Refrigeration units is mixed with that from the other systems (Compressors cooling, Kiln bearing cooling, etc.) and cooled in common cooling towers It is necessary to have a dedicated cooling tower for Refrigeration units. This will improve the performance of the condenser and hence the refrigeration units Actions have already been taken to provide a separate cooling tower for the refrigeration units

7.2 CANTEEN SYSTEMS

7.2.1 FACILITY DESCRIPTION

A Solar water heating system had been installed in canteen to produce hot water. This hot water is used in the following areas :

i) Steam cookers
ii) Washing & Cleaning purposes

The solar water heating system has 24 no of Flat Plate Collectors (2m x 1m collection area / plate) arranged in 3 modules. Each module has 8 no. of collectors connected in series The 3 modules are connected in parallel The water circulation is maintained by Thermosyphon principle

7.2.2 OBSERVATIONS

I) During our study period the solar water heating system was not functioning

II) It was claimed that the temperature of the hot water generated was 50 - 60°C during summer and 35 - 40°C during winter. Additional collectors can be installed to supply water at a higher temperature to the cookers, which will reduce its fuel requirement. Alternatively, more hot water could be generated at the above temperatures The canteen building has enough space in the terries to add another 18 - 20 collector plates of 2 m^2 collection area Economic feasibility of the proposal is worked out in the Appendix - 7/6

III) A thin coating of cement dust firmly adhered to the collector's glass surface was observed on all the collectors. This acts as partially opaque layer for the incident solar radiation falling on the absorber plate of the collector, reducing its efficiency. Though arrangements had been made for the cleaning of the glass surfaces regularly, coating formed by cement dust with moisture was not been cleaned effectively To avoid this problem methods like periodic acid cleaning of glasses could be resorted to

IV) The glass cover of one of the collectors was missing and the above said cement dust coating was observed on the absorber plate too Though these systems are maintenance free regular attention has to be given

V) Insulation provided on the hot water line had got damaged As this will dissipate the heat gained in the collector, it should be properly insulated

7.2.3 RECOMMENDATIONS

A. The hot water supply from existing solar water heating system is insufficient It is recommended to install additional solar flat plate collector water heating system of 2,000 lpd capacity, to generate more hot water The above proposal is expected to yield energy savings as enumerated below .

Annual fuel savings	=1650 kg of LPG
Annual energy savings	=180 lakh kcal
Annual cost savings	= Rs.39600/-
Investment cost	= Rs 240000/-
Simple payback period	= 6.06 years

8.0 LIGHTING SYSTEM

L&T ACW can be broadly classified into following areas for the purpose of Lighting system study

- Phase - 1
- Phase - II
- Cement Mill
- Packing Plant
- Street Light
- Colony
- Mines

This study covers measurement of lighting load, voltage condition, lux levels in factory area and identification of energy saving areas etc

Lighting load is contributing around 2 5% of total energy consumption. The adoption of energy efficient measures and effective housekeeping methods are discussed for optimum electricity consumption in the area of lighting

8.1 FACILITY DESCRIPTION

The plant makes extensive use of HPSV and fluorescent fixtures in different areas Earlier most of the phase-I luminaires were fluorescent fixtures and had been gradually changed over to more energy efficient HPSV fittings However phase-II luminaires were mainly HPSV (being relatively new) The structure of the cement plant helps in use of natural light in plenty

The total connected lighting load could not be ascertained in absence of any structured data (which has undergone changes over the years). However, an effort has been put to physically quantify, the details of lighting fixtures (Refer Annexure - 8/1) presently being used in Phase-I & Mines The Phase-II luminaires are slightly (15-20%) higher compared to Phase -I An analysis of fluorescent fixtures in substation (in both Phase-I & Phase-II) have been carried out and presented in Appendix - 8/2

It is also tried to quantify various area lights (mainly focus and flood light types) in use at present in factory areas (Phase-I & Phase-II). The details are tabulated in Appendix - 8/3

The colony lighting load consists of street lighting, Club/Sports ground lighting, domestic lighting and apparatus The ACW colony street light details are tabulated in Appendix - 8/4

In factory area the lighting load is mainly separated and fed through main lighting distribution boards The incomer to MLDB are fed from PCC modules in various substations There are no lighting transformers earmarked for this purpose leaving no scope of controlling the lighting circuit voltage at present

8.2 OBSERVATION, ANALYSIS AND FINDINGS

A. General

FACTORY AREA

i The plant has used extensively 70W HPSV lamps.

ii The atmosphere is quite dusty, thereby making it necessary to have a more frequent maintenance and inspection.

iii. The ambient temperature in some areas e.g. preheaters, coal feed, kiln feed area is higher than normal.

iv. There are number of conveyor ducts both underground and overground (e.g D.B.C, Coal conveyor, Pipe conveyor etc.) and Cable trench fitted with HPSV / fluorescent fixtures.

v. In general during daytime, the natural light is sufficient in most of the sections, except for D.B.C area

vi In most of the areas, local switch control is installed and timer control is used for switching the plant lighting

vii. It is observed that at many places, luminaires are completely covered with dust, the translucent sheets have turned yellowish and opaque, the tubes are either glowing pink or dim (i e black ring formation at both end) and some lighting points are not working This involves wastage of energy

This indicates that timely replacement /maintenance of luminaires is not being carried out due to constraints such as high bay maintenance etc

viii In some of the areas inequal distribution of luminaires has taken place over the years (e.g in Cement Mill, Packing Plant substation) which needs correction for balanced distribution

ix During the period of our study, it is observed that all the substation building's lights and cable trench lights are left 'on' for day and night even when there was no work done or person present

x. It is also observed that some of the flood lights, (e.g. coal yard, Phase-I Cement Mill, etc.) are left 'on' during day time inspite of no testing or maintenance being carried out This can be avoided by effective control While discussing with plant personnel, it is found that some of these lights have been connected to Emergency circuit of 24 hours during urgency of maintenance and needs to be altered or rectified in due course

xi In pipe conveyor conduit it is observed that one section of HPSV (70W) lamps are left 'on' during the day

xii. The plant management has already initiated practice of providing single tube in double fixture at selected locations and use of HPSV lamps for energy efficiency

xiii In office location normally the lighting is not being controlled as per occupancy even after having local switches

COLONY AREA:

i In colony street lighting, the plant has initiated a major energy conservation move by replacing all 250W HPSV with 70W HPSV lamps However, height of poles being unaltered the level of illumination have been low in between the poles and at road levels.

ii The street light poles are currently not connected in alternate phases, thereby making it difficult to switch 'off' alternate poles between 12 p m to 5 a m to achieve energy savings.

iii In many places, the branch of trees are blocking the luminaires.

iv. In some of the junctions, there is no specific dedicated light poles.

v. In some places, HPMV fixtures are used for by-roads.

vi. Street light fittings are mostly dust covered or gathering of insects inside the luminaires is causing blockage of light. Some of the acrylic covers require replacement

vii Number of incandescent lamps are observed to be in use in colony areas for a sustained period of more than 4 hours

viii There has been an introduction of voltage controller for colony lighting in 2 substations and no reactive compensation is done presently

ix The lighting levels near S T plant and roads leading to the plant needs to be improved

B. Lighting Load Parameters

Power measurements have been carried out on various L.D B locations to assess the system lighting load This is found to be as follows

Plant	514 33 kW	
Colony .	770 16 kW	(includes heaters & domestic equipments load)
Mines .	37 40 kW	
Total	1321 89 kW	

The details of measurements are indicated in Appendix 8/5.

The voltage level is observed to be at higher level in plant between 237 volts - 249 Volts and the P.F is observed to be between 0.6 - 0.8 lag Whereas in colony, it is between 233 volts-243 volts with p.f. of 0.69 - 0 98. The high p f at some D B's are due to heater loading in the winter. The neutral current I_N is observed to be higher in many cases in plant, which requires a review of maintenance

C. Illumination Levels

The lux levels are measured at various locations of the plant and presented in Appendix -8/6 Generally the level of illumination conform to the guide line prescribed in IS 3646 However, in some areas the lighting level requires improvement by way of strengthening, re-distributing fixtures or adopting proper maintenance schedule

D. Energy Efficient Lighting

By use of reduced voltage (to the tune of 210-230 Volts) exclusively for lighting circuit, a saving of 10 -15% lighting energy consumption can be achieved

The reduced voltage of the above mentioned level does not impair the ability of discharge lamps to strike, though an insignificant reduction in lumen output takes place The detailed study is presented in Appendix - 8/7

Besides, use of higher voltage tend to reduce the life of luminaires An inventory of consumption pattern (as enumerated in Appendix - 8/8) shows a trend of increased consumption over last two years, supports this fact inspite of observing number of non-attended points

ii. By adopting controlled switching of tubelight in substations and cable trenches, an energy savings to the tune of 1,17,945 kWh per annum is possible (Refer Appendix - 8/9).

iii. The best method to conserve lighting energy is to 'turn off' when not required. A necessary motivational campaign programme can be suitably devised to prevent wastage as enumerated in Appendix - 8/10

iv. Though during our discussion with plant maintenance officials, it is gathered that experience related to use of electronic choke have not been satisfactory Yet due to improved manufacturing process and standardisation adopted by manufacturers, reliable source of supply is currently available Use of electronic choke can help in substantial energy saving to the tune of 71,280 kWh per annum (as shown in Appendix - 8/11)

8.3 RECOMMENDATIONS

A. General

i The luminaires should be periodically cleaned and maintained Regular replacement of worn out tubes or luminaires are necessary to get maximum lumens per watt consumed

ii. Switch `ON ' to match the occupancy level in office areas or stores etc

iii. Organise for improvement of lux level in certain areas by way of adopting simple measures such as:

- Changing reflector/acrylic covers
- Reduce height of luminaires
- Reallocate available luminaires for equal distribution
- Observe regular maintenance schedule

Some of the areas and remarks may please be referred as listed in Appendix - 8/6 for implementation

iv. The plant maintenance should acquire a mechanical truck mounted telescopic platform for easy outdoor maintenance.

v Presently lot of area lighting of approximate 30 kW is in use without giving effective illumination Suitable highmast lighting with increased efficacy can be organised for better illumination in the areas at the locations indicated in the Plant layout drawing (Refer Fig 1)

Lighting manufacturers may be consulted for appropriate design of highmast lighting structures This will also enable management to have an effective control on switching and maintenance

vi The plant should replace all Fluorescent fixtures in dusty areas by HPSV lamps

vii. In the colony areas, reduction in the height of street lamp-posts should be taken - up.

viii. In junction or in important places of activity, re-introduction of 250W HPSV lamp and trimming of tree branches shall help in increasing the light level.

ix Decodify incandescent lamps from Store inventory and install energy meter at important points e g Canteen, Guest House, Club etc.

B. Energy Efficient Lighting

i Use of reduced voltage through exclusive lighting transformer deployed from current resources shall yield in following savings (Appendix - 8/7)

Annual Energy Savings	= 522720 kWh
Cost of Annual Energy Savings	= Rs 15 68 lakhs
Cost of Implementation	= Rs 15 lakhs
Simple payback period	= One year

ii Energy savings can be achieved through controlled switching by use of timers and by-passing circuit (Appendix - 8/9) as stated below

Annual Energy Savings	= 1,17,945 kWh
Cost of Annual Energy Savings	= Rs 3 54 lakhs
Cost of Implementation	= Rs 2 25 lakhs
Simple payback period	= 0 65 years

iii By Simple "SWITCH OFF " method the plant can prevent wastage of energy (Appendix - 8/10) as given below :

Annual Energy Savings	=	28,322 kWh
Cost of Annual Energy Savings	=	Rs.0.85 lakhs
Cost of Implementation	=	Rs 1.00 lakh
Simple payback period	=	1 year

iv Use of Electronic choke in controlled atmosphere and non dusty areas can yield savings of energy (Appendix - 8/11) as below :

Annual Energy Savings	=	71,280 kWh
Cost of Annual Energy Savings	=	Rs.2.14 lakhs
Cost of Implementation	=	Rs 5 40 lakhs
Simple payback period	=	2 5 years

8.4 SUMMARY OF POTENTIAL SAVINGS

Sl No	Recommendations	Annual Energy savings		Investment required	Simple Payback period
		kWh	Rs in Lakhs	Rs in Lakhs	Year
1	Energy savings by voltage control	522720	15 00	15.00	1 0
2	Energy savings by switching off through timers	117945	3 54	2.25	0.65
3	Energy savings through switching off during day time	28322	0 85	1.0	1.0
4	Installation of electronic chokes for fluorescent tubes	71280	2 14	5 40	2.5
Total		**740267**	**21.53**	**23.65**	-

9.0 ENERGY MANAGEMENT SYSTEM

9.1 INTRODUCTION

The energy bill of the unit runs to about Rs.90 - 108 crores per year, which will continue to escalate with the unavoidable rise in cost of electricity and fuels, in the coming years

In order to control the excessive consumption of energy and bring optimum possible savings in energy consumption, it is essential that an effectivè energy management system is put in operation in the organisation

Energy Management requires a logical and comprehensive management approach Energy savings become significant and long lasting when they are achieved as part of an overall plant energy management programme. A systematic and structural approach is essential to identify and realise the full potential savings

The most essential requirement for a successful energy management programme is the top management commitment An important part of top management commitment is to create an organisation for implementing the energy management programme This is commonly at two levels, the Energy Manager and the Energy Committee Evidence of top management commitment will be seen in the level of support given to the Manager and the Committee, in all respects

The basic requirements for the position and the job description of a typical Energy Manager are described at the end of this chapter.

MANAGEMENT APPROACH

Top Management Commitment

The most essential requirement for successful energy management programme is the commitment of top management They must visibly demonstrate their commitment to the employees of the enterprises

The decision of the company to control energy costs must be clearly stated and understood by all within the company. Senior management should participate in energy related activities. The company Chief Executive should regularly call for information/reports on the progress, particularly at the beginning of the energy management programme.

PRELIMINARY ANALYSIS

In order to develop a energy management programme in the proper perspective, it is necessary that the scope, extent of detail and the management cost and time expended should have some relation to the potential benefits realisable by the programme There is no point if the cost incurred is more than the value of energy saved.

The energy management programme should begin with the analysis like :-

- Consumption of different forms of energy
- Energy cost as a percent of total production cost
- Major energy consuming equipments and their diversity
- Potential savings and its comparison with current profits

- Estimate of costs of additional metering, that may be required - cost of introducing EM
- Within the existing company organisation how best can energy consumption be monitored in different areas or departments

Such broad assessment would give a perspective of the management time and cost value in relation to potential returns

C. ENERGY COMMMITTEE

In manufacturing industry, close co-ordination with different functions will be essential To achieve this co-ordination at larger manufacturing sites, an Energy Committee will be needed This may, for example, include senior managers, the Accountant and the Chief Engineer The Chairman should be the General Manager who has sufficient authority to ensure that all necessary resources are made available and any necessary action is taken

The Energy Committee will be responsible for :

- developing the energy efficiency policy
- managing the monitoring system
- agreeing and reviewing standards and targets
- examining energy cost-saving schemes and ensuring projects are implemented
- other important matters concerning energy

Once a corporate decision has been made to initiate an energy management programme, a management structure within the company's organisational framework needs to be created, in view of the special role of energy as a common input across different divisions, departments and sections

The energy management structure will depend on the size of the enterprises, its functional organisation, and its manufacturing activities.

ENERGY MANAGER

Looking at the size of energy bills, it appears essential that a full-time energy manager is appointed to implement the energy management programme The appointment of an Energy Manager would also demonstrate to the company employees, the management commitment and its seriousness in dealing with the problem

The Energy Manager should be appointed from within the plant, to ensure that he has good practical knowledge of all aspects of operations, both technical and administrative

RESPONSIBILITY FOR RESULTS

In general, most important structures in manufacturing industry will be based in three levels of authority with corresponding responsibilities for the efficiency of energy usage

Level 1 : Senior Management : With responsibility for the efficiency with which energy is used in the organisation as a whole, in relation to other resources, and in the production of particular products.

Level 2 : Middle Management : With similar responsibilities for the efficient use in relation to specific areas of the manufacturing process or divisions of the organisation

Level 3 : Process Operators, Foremen and Supervisors : With responsibility for maintaining control over the efficiency of energy use in a particular item of plant or part of a process

At all three levels, those responsible for controlling and improving the efficiency of energy usage will need regular reports on energy use in relation to standards and targets.

Providing these reports, analysing the energy data, developing standards of performance, and deriving the information needed for setting targets will be task of an Energy Manager who is responsible to the Energy Committee His duties may be also include responsibility for the installation and operation of metering systems and the training of staff responsible for the collection and analysis of energy data

ENERGY MANAGEMENT PROCESS/STRATEGY

There are four distinct stages

- Defining energy accounting centres
- Measurement
- Analysis & Monitoring
- Targeting

ENERGY ACCOUNTING CENTRES (EAC)

The first step in installing an energy management programme is to identify along the energy flow paths of the plant, a series of `Energy Accounting Centres' which will provide the requisite breakdown and frame-work necessary, both for monitoring energy performance and for achieving targets An Energy Accountable Centre might consist of individual equipments such as section/dept or even a whole building

Each centre must relate to a nominated individual responsible for operational achievement in that area Tying of resource consumption to that of operational achievement is a key factor in energy management programme, since it focuses attention of those with the authority to bring about improvements in performance

Those held accountable for energy performance should also be able to assess the performance and also have the pertinent information on which to base judgements, decisions and actions to bring about improvements

Each energy accountable centre (EAC) requires the facility of meters, to measure the energy consumed over a period and a means of measuring/assessing the production (or other specific variable) over the same period As far as possible the EAC's identified should correspond with existing cost control centres on the site.

B. MEASUREMENT

Before any resource can be managed effectively, it must be quantified correctly in order to provide the information upon which to base management decisions So, like all truly effective management systems, energy management depends on the collection of relevant data upon which to judge current performance and to plan for future improvements The gathering of this information forms an essential part of the monitoring programme

C. ANALYSIS & MONITORING

After collection of energy consumption and cost data, the next stage is to use that information to analyse and evaluate performance

Analysis and evaluation involve, regular comparison of actual levels of energy consumption with the amount of energy expected to be used as defined by a set of internally based standards. Difference between actual consumption and these standards will reveal either improvements in energy efficiency or a fall-off in performance levels In this way, the information produced by monitoring forms a basis for continuing performance evaluation and control

On the one hand, it will provide quantified evidence of exactly how successful have been the measures to improve performance. On the other, it will indicate if and where failures have occurred and trigger the necessary remedial action

Analysis should be a continuous process so that speedy action can be taken speedily if energy efficiency deteriorates And to ensure effective performance evaluation and control, each line manager or plant operator must receive the energy throughput and other figures regularly - on a weekly/ monthly basis - and promptly, so that departures from the standards can be quickly detected and corrected In turn, line managers themselves must ensure that they respond rapidly to the information they receive. And here, well designed reporting forms, expressed in readily understood energy cost terms, will be very helpful

Achieving greater energy efficiency depends on developing an energy management strategy that will maintain progressive reductions in energy consumption for the same or high levels of output And the foundation of effective energy management is the introduction of a system of monitoring to equip the managements with the information and the motivation to attain greater levels of energy efficiency

The essence of monitoring is that energy use is accurately measured, then compared with a set of standards derived from a knowledge of the organisation's own capability, and then possibly further checked by reference to external norms

By wielding the control and motivational aspects of energy management closely, monitoring provides a structured framework in which managers at all levels are able to optimise efficiency through the careful use of the energy resources for which they are responsible.

Just by the introduction of a monitoring system alone, many organisations have found that they can cut their energy consumption by up to ten percent

D. TARGETING

The first stage in the process of setting targets is to carry out an energy audit - a procedure which can with advantage be repeated every year

An energy audit will identify the possible range of energy efficiency improvement measures available and appropriate to the circumstances of an individual organisation It will also provide an estimate of their costs and the likely return in investment

From the results of the audit, management can select a series of measures to form an action programme - starting with the most cost-effective and taking into account, for example, the availability of capital and effect of the measures on the organisations other activities

In the first instance, the action programme may simply involve changing working practices or adjusting machinery It may then move on through low cost improvements, like plant and pipework insulation, to investment in higher cost measures, such as heat recovery equipment or more energy-efficient plant

Targets are then set for the implementation of change and the achievement of the predicted energy cost savings The choice of targets will take account of current standards and the timescale for implementing measures. And an organisation may wish to set a range of targets, taking account of the scope for improvement, the resources allowed by management to effect improvement and the need to match accountability to the energy - accountable centres

There are two principal methods of target setting In the first place, the so called `top down' approach, a broad based generalised technique which does not draw on a detailed analysis of the circumstances of the organisation but may be based on experience in the sector as a whole. In the second place, the `bottom up' which is based on a close knowledge of the energy requirements of different parts of an organisation's activities. Both systems have their merits and which one is chosen depends on circumstances and cost-effectiveness

Experience has shown, however, the most organisations prefer the `bottom up' approach since it is, by its very nature, more closely tailored to their business needs and hence more effective in providing motivation

Correctly set, targets have a strong motivational effect on the workforce. But it is important to avoid either impossible or too easy obtainable targets since these can provide counter productive

9.4 IMPORTANCE OF HUMAN ELEMENT

In the implementation of E.M. Process getting the human element right is vital to the success, like any management system So when introducing energy management into an organisation, it is essential to put people first of all, to establish a chain of managerial responsibility which reaches right up to senior management and which can motivate improvements in energy efficiency throughout the organisation

Some Means of Getting Fuller Co-operation of Personnel are :-

A. Education

A well thought-out familiarisation programme should convince employees of the need for good standards of housekeeping and energy awareness They should appreciate, that it is in their best interests that all unnecessary and excessive use of energy be eliminated

Energy cost savings add directly to profit They will help safeguard, the employees' future by improving the firms economic well-being and competitiveness Moreover, each rupee saved is equivalent to many rupees worth of extra production It is important to emphasise that sacrifices are not being sought, nor are the staff being expected to work in less than satisfactory conditions

Early encouraging results are unlikely to be sustained indefinitely People do tend to drift back into their former habits, but the right climate of opinion will be established for introducing more complex, and lasting measures in a gradual manner

B. Awareness and Information Sharing

In most plants, employees have little or no idea of the amount of energy being consumed within their plant, their section and even the equipment being operated by them. In such a situation, energy conservation obviously carries no meaning

Employees can be stimulated to support energy management by making them aware of the amount of energy they are using, the associated costs, the many ways to save energy, and the importance of energy conservation for the company's viability/profitability

The information can be provided in the form of comparisons of historical trends, goals for overall energy use, energy intensity, etc., in both physical and monetary terms , energy conservation checklists for each manufacturing operation outlining simple and routine housekeeping measures to save energy, audio-visual presentations, and other literature.

Information must be presented in a manner which facilitates comprehension If the information is too technical, too much theory, too sketchy, or too dull, it is likely to be ignored or not understood

Terms that employees can relate to in everyday life should be used For example, a sign saying " stop steam leaks" will not be as effective as a sign saying " A quarter inch diameter steam leak costs Rs.30,000 per month".

Training is also an important means of both informing and involving people at all levels in an energy management programme.

For operating personnel, training is required in practicalities of energy saving This could be integrated into the organisation's other training programmes.

Upper level management also need to be informed of the overall energy situation, energy costs in relation to other costs, the energy management programmes - its goal, achievements, technical, economic and behavioral aspects ètc.

C. Motivation

Motivation is based on involvement and commitment · and a sense of personal accountability can be generated only through total involvement of plant personnel at all stages.

Involvement must begin with the top management As mentioned earlier, top management must be fully committed to the energy management programme and must visibly demonstrate their commitment and involvement in every manner possible and at every available opportunity. Top management must originate the programme, generate momentum and then maintain momentum

Adequate personnel and financial resources must be provided and responsibilities delegated to implement activities and projects to achieve the predetermined energy conservation goals. Progress should be monitored and goals reviewed and revised in the best interests of the company

Operators and maintenance staff should be involved actively, as they are ultimately responsible for execution of activities in the programme. Also, they are often in a better position to recommend areas for savings or improvements The most effective way of involving them is by simply going out and talking to them regarding goals, achievements, problems and progress or lack of progress This demonstrates to them that the energy conservation programme is real and also that their role is important in success or failure of the programme

Supervisors and middle level management should be involved by assigning them responsibilities for implementing and monitoring activities and submitting performance reports to top management, and by getting them to interact and communicate with operators and maintenance stand on progress and problems If possible, energy management activities should be made a part of each supervisor's performance or job standard.

D. Incentives and rewards

Another method of motivating people is through incentives and rewards. Monetary rewards could be given to employees for suggestions leading to substantial energy savings , for innovative ideas or solutions , and for outstanding efforts in implementation of energy conservation activities Wide publicity of effective idea provide an added incentive in the form of public recognition Other incentives could be designed to meet the needs and attitudes of plant personnel

E. Publicity

Publicity and promotion are essential to create climate for the energy management programme Some commonly used means for publicizing and promoting and energy conservation programmes are :-

1 One article per month written in the company or plant paper or one good energy conservation idea that was implemented.

2. Articles from the company or plant paper used to obtain local newspaper interest and coverage

3 Posters and pamphlets on energy conservation.

4. Letterheads with different energy conservation messages and ideas printed

5 Plant-wide, high-visibility vehicles or equipment are used to carry signs publicizing energy conservation

6. Energy conservation performance results for plant and department, posted, monthly by the plant energy manager

7 Plant energy manager having face-to-face energy conservation discussions with plant personnel The opportunity checklist can be used for discussion topics.

8 Unit representatives and several unit personnel conduct quarterly on site reviews, a walkthrough of the unit looking for energy saving opportunities.

9 An agenda item in energy conservation included at staff meetings.

10. Energy conservation material provided to first-line supervisors for employee discussion periods, quarterly.

11 Quarterly meetings held in the plant for all unit representatives.

12 An Energy Awareness Day is set aside in the plant twice a year.

13 A company energy logo developed and adopted.

9.5 KEY TASKS OF ENERGY MANAGEMENT

(1) Energy Data Collection and Analysis

* maintain records of all energy consumption in the plant

* check the reading of all meters and submeters on a regular basis.

* specify additional meters required to provide additional monitoring capability

* develop indices for specific energy consumption relative to production and maintain these indices on a monthly basis for all major production areas.

* set performance standards for efficient operation of machinery and facilities

(2) **Energy Purchasing Supervision**

* review all monthly utility and fuel bills ; ensure billing is proper and that the optimum tariff is applied in each base.

* investigate and recommend fuel switching opportunities where a cost advantage to the company is possible.

* develop contingency plans to implement in the event of supply interruptions or shortages.

* work with individual departments to prepare annual energy cost budgets

(3) **Energy Conservation Project Evaluation**

* develop energy conservation ideals and projects, working with in-house staff, equipment vendors and outside consultants

* summarise and evaluate possible energy saving projects according to the company financial planning requirements ; perform the necessary economic analyses to permit management evaluation of the projects

* obtain management commitment of funds to implement conservation projects

* re-evaluate possible projects as the company operations change or grow , evaluate energy efficiency of new construction, building expansion or new equipment purchases.

(4) Energy Project Implementation

* initiate equipment maintenance programmes for energy saving

* supervise the implementation of conservation projects, including specification of equipment, requests for quotation, evaluation of offers, ordering of materials, construction/installation, operator training, start-up and final acceptance.

(5) Communications and Public Relations

* prepare monthly reports to management, summarizing monthly energy costs and consumptions as well as specific energy consumptions

* communicate with all production and support departments, so that all participate in the energy management programme

* develop an awareness programme within the company to encourage active participation by all employees in energy saving activities

* develop training programmes to upgrade knowledge and skills of all levels of employees in energy related matters.

* publicise the company commitment to energy conservation where appropriate, providing information for press releases and internal notices, presenting papers in professional conferences, and entering the company in energy award programmes.

9.6 CHECKLIST FOR TOP MANAGEMENT

A. Inform line supervisors of :

1. The economic reasons for the need to conserve energy.

2. Their responsibility for implementing energy saving actions in the areas of their accountability.

B. Establish a committee having the responsibility for formulating and conducting an energy conservation programme and consisting of :

1. **Representatives from each department in the plant**

2. A co-ordinator appointed by and reporting to management

C. Provide the committee with guidelines as to what is expected of them :

1 Plan and participate in energy saving surveys

Develop uniform record keeping reporting and energy accounting

3 Research and develop ideas on ways to save energy.

4 Communicate these ideas and suggestions.

5 Suggest tough, but achievable, goals for energy saving

6 Develop ideas and plans for enlisting employee support and participation

7. Plan and conduct a continuing program of activities to stimulate interest in energy conservation efforts

D. Set goals in energy saving :

1 A preliminary goal at the start of the programme.

2 Later, a revised goal based on savings potential estimated from results of surveys

E. Employ external assistance in surveying the plant and making recommendations, if necessary

F. Communicate periodically to employees regarding management's emphasis on energy conservation action and report on progress

DUTIES AND RESPONSIBILITES OF ENERGY MANAGER/CO-ORDINATOR

* To generate interest in energy conservation and sustain the interest with new ideas and activities

* To maintain summaries of energy purchases, stocks and consumption, and to review and report on energy utilisation regularly.

* To be the focal point for departmental records of energy use, and to ensure that the records and accounting systems are uniform and in consistent units.

* To co-ordinate the efforts of all energy users and to set challenging but realistic targets for improvements

* To give technical advice on energy-saving equipment and techniques, or to identify suitable sources of sound technical guidance on specialised subjects

* To identify areas of plant activity which require detailed study and to give priority to such activities.

* To maintain records of all-indepth studies and to review progress

* To provide a basic handbook of good energy practice for the plant operating department

* To give specialist advice to purchasing, planning, production and the other functions of all aspects of energy conservation, especially on the long term implications.

* To ensure that, in making improvement in energy efficiency, health and safety are not adversely affected.

* To liaise with committees and working groups within his own industry, and provided no confidential data are involved, to exchange ideas on cost cutting techniques and performance figures for similar processes

* To maintain contacts with research organisations, equipment manufacturers and professional bodies to ensure that he is up-to-date on significant developments in the field of energy conservation.

* To remain up-to-date on national energy matters and to advise senior company management on such topics, as well as co-operating with government departments in energy-related matters

10.0 CHECK LISTS FOR COMPRESSED AIR SYSTEMS

In order to keep compressed air system efficient, various checks and inspections are recommended These are summarised in the form of check lists.

1. **Free Air Delivery Test**

   Compressor free air delivery test (FAD) has to be done periodically to check the present operating capacity against its designed capacity If actual FAD is within the acceptable limit (more than 85% of rated FAD), it will also result in higher compressor efficiency. The methodology to conduct FAD test is given in Appendix - 10/1 If the actual FAD is less than 85% of rated FAD, the following measures are recommended

   a Clean air inlet filters regularly Choked filter will reduce FAD and it will reduce compressor efficiency by 2% for every 25 m bar pressure drop across the filter.

   Install manometers across the filter and monitor the pressure drop as a guide to replacement of filter element Keep suction air velocity below 1400 m/min

   b Keep compressor valves in good condition by removing and inspecting the valves once in six months Thoroughly clean the valves and closely inspect them for wear and broken or defective parts Worn out valves reduce FAD and it can reduce compressor efficiency by as much as 50%.

c Keep an hourly log of air temperature, water temperature and gauge pressure Use interstage pressure and temperatures to detect abnormal conditions.

A decrease in the interstage pressure and temperature means that the lower pressure cyclinder has reduced capacity An increase in interstage pressure and temperature means that the next higher stage cylinder has reduced capacity. These conditions can be attributed to leaking valves and gaskets, worn out piston rings or broken parts

d Check the compressor piston rings for wear once in six months The standard recommendation is to replace piston rings when they have worn out to half their original thickness when rings wear past this point, ring end gaps become excessive and increased blow by past the rings will reduce the cylinder efficiency

e Inspect valves passages and cylinder bores once in six months Remove any accumulation of foreign material.

f Fouled intercoolers will reduce compressor efficiency and cause more water condensation in air receivers and distribution lines resulting increased corrosion. Periodic cleaning of intercoolers has to be ensured.

2. Leakage in Compressed Air System

Compressed air leakage of 40-50 percent is not uncommon. They can be brought down to less than 10 percent. It requires identification and removal of all leaks Most leaks occur at loose pipe fittings, shut off valves, worn-out filters, quick couplers and unused air tools Carry out leakage (no-load) tests periodically to locate leakage points The methodology to conduct leakage test is given in Appendix -10/2

a Operation of automatic electronic moisture drain trap timer has to be optimised depending on the season to minimise wastage of compressed air along with condensed water

b All pneumatic equipments be properly lubricated which will reduce friction, prevent wear of seals and other rubber parts thus preventing energy wastage due to excessive air consumption or leakage

c Misuse of compressed air such as body cleaning, agitation, general floor cleaning, personnel comfort and other similar applications have to be discouraged in order to save compressed air and energy

d Check manual drain for proper drainage to prevent condensate build up and check safety valves to prevent excessive pressure and wear

e If reservoirs fail to charge, check for air leakage in the by pass valves.

f Conduct in-plant seminars on maintenance, stressing on reduction of air wastage and improvement of air equipment performance

3. **Efficient Usage of Compressed Air**

a Install solenoid cut off valves in the air system so that air supply to a machine can be switched off when not in use

b Pneumatic tools such as Drills, Grinders consume about 20 times more energy than motor driven tools. Hence it has to be efficiently used

c Blow guns for cleaning off swarf or moisture have to be operated at the lowest satisfactory pressure rather than higher pressure For example at 1 4 bar a blow gun uses one third of the air, which it would have used at 6 2 bar.

d Keep nozzles in good condition An worn-out sandblast nozzle from 8 mm to 10 mm dia will use an additional 1.9 m^3/min compressed air

e Pneumatic equipments should not be operated above its recommended operating pressure as this not only wastes energy but also can lead to excessive wear & tear with further energy wastage

f Consideration may be given to regenerative air driers, which use the heat of compression in their operation.

g The possibility of utilising hot compressed air for heat recovery to generate hot air or water for process application has to be economically analysed for large compressors.

4. Effective Utilisation of Compressors

a Minimise low load compressor operation ;if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor.

b If more than one compressor is feeding to a common header, compressors have to be operated in such a way that only one small compressor should handle the load variation where as other compressors will operate more or less at full load

c Consideration should be given to two stage or multistage compressor as it consumes less power for the same air output than single stage compressor Oversized compressors lead to power wastage

d If pressure requirements for a process are widely different (eg 3 bar to 7 bar), it is advisable to have two separate pressure systems Reduce compressor delivery pressure wherever possible to save energy

e Provide extra air receivers at points of high periodic air demand which permit operation without extra compressor capacity

f. Retrofit modern speed regulation controllers in big compressors, say over 100 kW, to eliminate the `unloaded' running altogether.

g Use delay timers to limit the number of compressor motor starts to reduce start up loads, maximum demand and to lengthen the life of the compressor.

h Check lubricating oil consumption from performance records and manufacturers specifications For three or four stage compressors, lube oil consumption of 0.11/1000 kWh is typical

i Vibration of equipments should be monitored for identifying excessive vibration, which suggests misalignment, foundation settlement, out of balance rotors, worn bearings, bent shafting or damaged drive coupling

j Check availability of system (Note . availability is the annual time during which the compressed air system is ready for operation divided by the total time hours in a year, expressed in percentage). From this, it is possible to determine whether the plant is operating at its rated utility factor and prescribe necessary operation schedule

k Present energy prices justify liberal designs of pipe line size and layouts to reduce pressure drops A smaller dedicated compressor can be installed at load point which is located far off from the central compressor house instead of supplying air through lengthy pipe line.

5. **Instrumentation for Compressed Air system**

a Inspect instrumentation system frequently to ensure that operating oil pressure and temperature agree with manufacturer's specifications The instrumentation required for compressed air system is given in Appendix - 10/3.

b Check air compressor logs regularly for abnormal readings, especially motor amps, cooling water flow and temperature, interstage/discharge pressures and temperatures and compressor load cycle

6. **Power Consumption**

a Ensure air intake to compressor is not warm and humid by locating compressors in a well ventilated area or by drawing cold air from outside Every 4 ° C rise in air inlet temperature will increase power consumption by 1 percent

b Periodically adjust tension in drive belts of compressor V-belts can be retrofitted with flat belts for efficient operation and for 10% reduction in the power consumption

c Pneumatic instrumentation can be replaced by electronic instrumentation. Pneumatic transport can be replaced by mechanical system as it consumes about 8 times more energy Highest possibility of energy savings is expressed by reducing compressed air use.

11.0 ACKNOWLEDGEMENT

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A list of suppliers and retrofits is attached as Appendix - 11/1 for the perusal of management

APPENDICES

APPENDIX - 2/1

MONTHWISE PRODUCTION DETAILS
PHASE - I & II

Month & Year	Cement Production (Tonnes)	
	Phase - I	Phase - II
April 1995	102073	119617
May	87666	140180
June	102064	95707
July	89600	96221
August	68419	126878
September	75738	107777
October	107997	67284
November	122934	82903
December	113489	124547
January 1996	95253	121476
February	62638	115908
March	79073	166117
April	73613	142542
May	75511	155508
June	71982	152096
July	74540	156098
August	65827	121606
September	58367	109648
October	65252	116862
November	114732	109345

APPENDIX - 2/2

MONTHWISE ENERGY CONSUMPTION

PHASE - I & II

Month & Year	kWh/T of Cement	
	Phase - I	Phase - II
April 1995	118.3	111 5
May	121.9	113.4
June	118 6	114.4
July	119.6	140.0
August	120 2	127.2
September	124.1	124.3
October	135 3	124.2
November	121 8	121.6
December	119 3	124.8
January 1996	118 7	122 2
February	120 6	124.9
March	113 0	113.4
April	115 9	117.0
May	118 8	115.4
June	114.9	121.9
July	115 6	118.6
August	121.9	150.0
September	119 6	124.2
October	157 6	118.2
November	114 8	115.3

APPENDIX - 2/3

DEPARTMENTWISE POWER CONSUMPTION (kWh/T OF CEMENT)

PHASE - I

Department	Target	Actual							
	kWh/T of cement	(kWh/T of cement) 1996							
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Mines (L.S.Crusher-I) & Quarry	2.50	3.5	3 2	3.4	4 0	4.7	3.9	5.0	3.8
Raw Mill - I	30 0	32 8	33 7	31 0	32.5	32.9	31.5	35.0	29.7
Coal Mill - I	7 70	5.7	5 8	5.9	6 1	6.7	6 3	7 6	6.0
Kiln - I	35.50	37 5	38 0	38 1	35 4	37.7	37.2	56.9	36.4
Cement Mill - I	37 0/42 0	27 6	28.6	27 7	28.9	31.3	32.1	31.7	31.1
Cement Mill - II	37 0/42 0	-	-	-	-	-	-	32.5	30.8
Packing Plant - I	1 8	1.9	1.9	1 8	1 9	2.0	2.4	1.8	1.8
Factory Lighting	2.0	1.7	2.0	1.7	1 6	1.6	1.6	5.6	1.5
Colony Lighting	0.5	1 7	1 9	1.9	1.9	1.8	1.7	6.2	1.6
Workshop & Pump house	0 60	1 8	1 9	1.6	1.7	1.8	1.7	5.2	1.4
TOTAL	**119.5**	**115.9**	**118.8**	**114.9**	**115.6**	**121.9**	**119.6**	**157.6**	**114.8**

DEPARTMENTWISE POWER CONSUMPTION (kWh/T OF CEMENT)
PHASE - II

Department	Target	Actual							
	kWh/T of cement	(kWh/T of cement) 1996							
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Mines (L.S Crusher-2) & Quarry	2 5	3.5	3.3	3.3	3.9	3.7	3.9	5.0	3.5
Raw Mill - 2	31 00	33 7	32.4	35.1	34 6	36.8	34.9	30.2	30.4
Coal Mill - 2	5 70	4 5	4 3	4 6	5.0	5.8	5.2	5.0	5.0
Kiln - 2	27 0	31.3	31.2	33.1	30.3	39.4	29.4	29.2	27.9
Cement Mill - 3	41 3/41 0	33 4	34 2	34.7	35.3	38.7	39.5	39.9	38 9
Cement Mill - 4	41 0/55 0	40 4	39 8	39.6	39 4	42.2	44.9	41.8	43.4
Packing Plant - 2	1.8	1.8	1.9	1.8	1.9	2.0	2.5	1.9	1.8
Factory Lighting	1.6	2.0	2.0	2.5	1.8	9.0	2.0	1.9	1.7
Colony Lighting	0 5	1.4	1.3	1.8	1.5	7.2	1.7	1.5	1.4
Workshop & Pump House-2	0.6	0.6	0.6	0.7	0.6	1.7	0.7	0.7	0.6
TOTAL	113.3	117.0	115.4	121.9	118.6	150.0	124.2	118.2	115.3

APPENDIX - 3/1

DETAILS OF TRANSFORMER NAME PLATE & TEST CERTIFICATE

POWER TRANSFORMERS

DESCRIPTION		PHASE # I		PHASE # II	
TRF. ID Code No		TR-1	TR-2	TR-3	TR-4
Application/ Location		MSS	MSS	MSS	MSS
Type		ONAN/ ONAF	ONAN/ ONAF	ONAN/ ONAF	ONAN/ ONAF
Rating inMVA	- ONAN	16	16	20	20
	- ONAF	20	20	25	25
Voltage in kV	- HV	66	66	66	66
	- LV	6 9	6 9	6.9	6.9
Current in Amp.	- HV	175	175	218.7	218.7
	- LV	1674	1674	2092	2092
% Impedence in Ohms		8%	8%	9 30%	9 42%
Vector Group		Dyn11	Dyn11	Dyn11	Dyn11
O.L.T.C. (Yes/ No)		Yes	Yes	Yes	Yes
Tap Setting		+7.5% to 12.50%	+7 5% to 12.50%	+7.5% to 12.50%	+7.5% to 12.50%
No Load Loss kW		11 5	11 5	-	-
Full Load Loss kW		65	65	-	-

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DISTRIBUTION TRANSFORMERS - PHASE # I

DESCRIPTION	HPC-1	HPC-2				HPC-2A		HPC-3			HPC-4
TRF ID Code No	T-11	T-21	T-22	T-23	T-24	T-2A1	T-2A2	T-31	T-32	T-33	T-41
Application/ Location	RAW MILL PCC	PCC-2 COAL MILL	PCC-2 COAL MILL	PCC-2 COAL MILL	435 kW KILN MAIN WIWO3	PCC-2A Kiln feed	PCC-2A Kiln feed	PCC-3 Cem Mill	PCC-3 Cem Mill	PCC-5 Packing PH	Lime Crushing MCC-4-3
Type	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN
Rating in kVA	1600	1600	1600	1600	800	1600	1600	1600	1600	1600	750
Voltage in kV - HV	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6.6
- LV	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0.433
Current in Amp - HV	140	140	140	140	70	140	140	140	140	140	65
- LV	2133 5	2133 5	2133 5	2133 5	1067	2133 5	2133 5	2133 5	2133 5	2133 5	1000
% Impedence in Ohms	6%	6%	6%	6%	4 75%	5%	5%	6%	6%	6%	5%
Vector Group	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11	Dyn1	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11
Off Load .Tap Setting	3	3	3	5	5	3	3	2	3	3	3
No Load Loss kW	2	2	2	2	1 5	2	2	2	2	2	1 5
Full Load Loss kW	17	17	17	17	11	17	17	17	17	17	11
Average Load in Amp.	660	730	978	550	500	400	540	621	600	450	400
Peak Load in Amp	720	760	1040	650	650	400	800	750	750	850	400

Appendix - 3/1 contd..

DISTRIBUTION TRANSFORMERS - PHASE # II

DESCRIPTION	SS-1		SS-2	SS-2A			SS-2B		SS-3		
TRF ID Code No	T12	T11	T22	T2A1	T2A2	T2A3	T2B1	T32	T33	T35	T36
Application/ Location	Raw Mill	PCC-1 Raw Mill	PCC-2 Coal Mill s/s	PCC-2A Coal Mill s/s	PCC-2A Coal Mill s/s	540 kW Kiln Main Drive	PCC-2B Kiln feed s/s	PCC-3 Cem Mill s/s	PCC-3 Packing Plt	PCC-3A Compressor	PCC-3A Compressor
Type	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN	ONAN
Rating in kVA	1600	1600	1600	1600	1600	1000	1600	1600	1600	1600	1600
Voltage in kV - HV	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6 6	6.6	6 6
- LV	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0 433	0.433
Current Amp - HV	140	140	140	140	140	87 5	140	140	140	140	140
- LV	2133 5	2133 4	2133 5	2133 5	2133 5	1333 4	2133 5	2133 5	2133 5	2133.5	2133.5
% Impedence in Ohms	5%	6%	6%	6%	6%	5%	6%	6%	6%	6%	6%
Vector Group	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11	Dyn11
Off Load Tap Setting	3	3	3	3	3	3	3	3	2	2	2
No Load Loss kW	2	3	2	2	2	1 9	2	2	2	2	2
Full Load Loss kW	17	17	11 5	17	17	11 5	17	17	17	17	17
Average Load in Amp	288 89	683	461 11	908 33	1216 67	897 2	800	645	567	150	650
Peak Load in Amp	400	750	800	950	1250	900	800	950	600	150	800

APPENDIX - 3/2

MONTHLY ENERGY CONSUMPTION DATA

Month	MD (kVA)	Total Units kWh	kW MD	Load Factor	Power Factor
Jan-93	48120	16908000	44040	0 532	0 910
Feb-93	54000	25192800	48600	0 771	0.920
Mar-93	53280	26744400	49440	0 754	0 93
Apr-93	53375	26949170	48125	0 726	0 910
May-93	54062 5	26113129	49062	0 740	0 910
Jun-93	51875	22555000	47500	0 637	0.920
Jul-93	55250	22645000	50312	0 626	0 920
Aug-93	51000	24382500	46562	0 752	0 914
Sep-93	50000	22040000	45625	0 670	0 920
Oct-93	51000	27363750	46937	0 760	0 910
Nov-93	52375	22488750	47375	0 681	0 910
Dec-93	50625	26696250	45750	0 759	0.910
Jan-94	47187 5	24373750	42812	0 767	0.910
Feb-94	48250	16281250	44250	0.552	0.917
Mar-94	50750	25340000	46250	0 785	0.911
Apr-94	50000	28688750	45625	0 750	0 907
May-94	47000	21175000	42375	0.764	0 907
Jun-94	47188	25503750	43437	0 765	0.920
Jul-94	46315	16557500	42187	0 565	0 941
Aug-94	45000	25607845	41875	0 800	0.939
Sep-94	46250	21665000	43000	0 692	0.940
Oct-94	48750	26235000	44750	0 796	0.931
Nov-94	47812 5	22772500	44250	0 708	0 943
Dec-94	48163	25148750	44062.5	0 745	0 930
Jan-95	49688	24226250	45500	0 794	0 930
Feb-95	50375	22968750	46000	0 742	0 929
Mar-95	52187 5	30327500	48750	0 787	0 934
Apr-95	54375	26357500	50312.5	0 681	0.927
May-95	54688	24590000	49812 5	0 708	0 932
Jun-95	54063	25108750	49375	0 684	0 937
Jul-95	50000	20842500	45937	0 631	0 934
Aug-95	49063	26245000	45312 5	0 711	0 931
Sep-95	51000	23281250	46000	0.752	0.929
Oct-95	50000	19750000	46250	0 613	0.91
Nov-95	53438	29761950	49430 15	0 784	0 916
Dec-95	56670	27590810	52419 75	0 731	0.910
Jan-96	54700	27841380	50597 5	0 674	0 9
Feb-96	52060	21933230	48155 5	0 703	0 93
Mar-96	51870	28475360	47979 75	0 824	0 93
Apr-96	51980	29559010	47821 6	0 831	0 92
May-96	51420	26622420	47306 4	0.782	0 91
Jun-96	51320	27038300	47214 4	0 770	0.92
Jul-96	50440	28104060	46404 8	0 841	0.92
Aug-96	50000	20703830	46000	0.605	0 92
Sep-96	49920	24014510	45926.4	0 703	0 93
Oct-96	45270	20150160	41648 4	0 672	0 92
Nov-96	54210	26006720	49873 2	0 701	0 91

APPENDIX - 3/3

HT CAPACITOR DETAILS

SL No.	LOCATION	ID CODE No.	SYSTEM VOLTAGE kV	CAPACITOR BANK kVAR
A	PHASE # I			
(i)	HPC - 1			
1	RAW MILL	R1M03	6.6	900
2	- do -	R1M23	6 6	900
3	- do -	R1S01	6.6	75
4	- do -	R1S04	6.6	75
5	- do -	R1P05	6.6	222
			Sub total =	2172
(ii)	HPC 2 & 2A			
1	KILN FEED	J1J01	6 6	429
2	- do -	J1J03	6.6	84
3	- do -	J1P44	6.6	75
4	COAL MILL & COOLER	K1M03	6 6	101
5	- do -	W1P51	6.6	101
6	- do -	W1K16	6 6	75
7	- do -	W1K17	6.6	75
			Sub total =	940
(iii)	HPC - 3			
1	CEMENT MILL	Z1M03	6.6	429
2	- do -	Z1M23	6 6	429
3	- do -	Z2M03	6 6	429
4	- do -	Z2M23	6 6	429
5	TRANSFORMER	T33	6 6	900
			Sub total =	2616
(iv)	HPC - 4			
1	HAMMER CRUSHER	A0M01	6 6	241
2	HAMMER CRUSHER	A0M02	6.6	241
			Sub total =	482
			Gr. total =	6210

Appendix - 3/3 contd.

HT CAPACITOR DETAILS

SL No.	LOCATION	ID CODE No.	SYSTEM VOLTAGE kV	CAPACITOR BANK kVAR
A	**PHASE # II**			
(I)	**SS - 1**			
1	RAW MILL	R2M03	6.6	800
2	-do-	R2M23	6.6	800
3	-do-	R2S01	6.6	84
4	-do-	R2S04	6.6	84
5	-do-	R2P05	6.6	127
6	BUS	BUS	6.6	1500
			Sub total =	**3395**
(II)	**SS - 2**			
1	KILN FEED	J2J01	6.6	504
2	-do-	J2J03	6 6	125
3	-do-	J1P09	6 6	158
4	ENVIROCARE PUMP	ENV 1	6 6	60
5	-do-	ENV 2	6 6	60
6	-do-	ENV 3	6.6	60
7	-do-	ENV 4	6 6	60
			Sub total =	**1027**
(III)	**SS - 2A**			
1	COAL MILL	K2M03	6 6	115
2	-do-	K2T01	6 6	153
3	-do-	W2P31	6 6	125
			Sub total =	**393**
(IV)	**SS - 3**			
1	CEMENT MILL	Z3M03	6 6	1512
2	-do-	Z4M03	6.6	1512
3	BUS	BUS	6.6	1500
			Sub total =	**[illegible]524**
(V)	**MINES**			
1	Primary Crusher	A3M01	6.6	200
2	Secondary Crusher	A3M02	6.6	250
			Sub total =	**[illegible]50**
			Gr. total =	**9789**

Appendix - 3/3 contd.

LT CAPACITOR BANK DETAILS

SL No.	LOCATION	ID CODE No.	SYSTEM VOLTAGE V	CAPACITOR BANK kVAR
A	PHASE # 1			
1	PCC - 1		433	286.8
2	PCC - 2A		433	275
3	HPC - 4		433	150
4	PCC - 2		433	350
			Sub total =	1061.8
B	PHASE # 2			
1	SS - 1	T21	433	325
2	- do -	T22	433	325
3	SS - 2	T22	433	325
4	- do -	BUS ***	433	325
5	SS 2 A	T12A	433	425
6	- do -	T22A	433	425
7	SS - 2B	T12B	433	425
8	SS - 3	T32	433	325
9	- do -	T33	433	325
10	- do -	T35	433	425
11	- do -	T36	433	0
			Sub total =	3650
			Gr.total =	4711.8

Time	kV_{L-L}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
11.20	60.6	394	48.2	35.0	34.6	35.3	402	390	390	38160	41280	15840	0.92	13080	12480	12720	6852	2772	0	0
11.25	60.6	404	48.0	35.0	34.6	35.3	410	402	398	38640	42360	17160	0.91	13200	12720	12840	10308	4248	0	0
11.31	60.6	412	48.6	35.0	34.6	35.3	418	408	408	39840	43200	16680	0.92	13560	12960	13200	14256	5928	0	0
11.35	60.6	418	48.6	35.0	34.6	35.3	428	414	414	40800	43920	16320	0.93	13920	13320	13560	16932	7032	0	0
11.40	60.6	406	48.6	35.1	34.7	35.5	414	404	404	39600	42840	16200	0.93	13440	12960	13200	20292	8412	42720	39000
11.46	60.6	426	48.8	35.2	34.7	35.5	436	424	422	41640	45000	16920	0.93	14280	13680	13800	24312	10044	43320	39240
11.50	60.6	404	48.6	35.1	34.7	35.5	412	402	402	39480	42600	16200	0.93	13440	12840	13200	26952	11124	43320	39240
11.55	60.6	404	48.6	35.2	34.7	35.4	414	400	400	39360	42600	16320	0.92	13440	12840	13080	30252	12480	43560	39480
12.02	61.2	418	49.7	35.4	35.0	35.6	428	416	414	41520	44400	15600	0.94	14160	13560	13800	34740	14268	43680	39720
12.06	61.2	424	50.8	35.4	35.0	35.7	432	424	420	42480	45120	15000	0.94	14520	13920	14040	37524	15276	43800	39960
12.10	61.2	416	50.9	35.5	35.1	35.8	420	424	410	42240	44280	13560	0.95	14520	13920	13800	40332	16260	44160	40320
12.17	61.2	440	50.4	35.3	34.9	35.5	448	444	428	43560	46440	16080	0.94	14880	14400	14280	44520	17748	44280	40680
12.21	61.2	414	49.9	35.5	35.1	35.8	422	412	408	41400	44160	15240	0.94	14160	13560	13680	47304	18768	44280	40680
12.25	61.2	404	49.3	35.5	35.1	35.8	412	402	396	40200	42960	15120	0.94	13680	13200	13320	50028	19788	44520	41040
12.32	61.2	396	48.8	35.3	34.9	35.7	402	394	394	39000	42000	15600	0.93	13200	12720	12960	54720	21600	44640	41160
12.36	60.6	396	48.5	35.1	34.[illegible]	35.5	404	396	392	38640	41760	15840	0.93	13200	12720	12840	57336	22644	44640	41160
12.40	60.6	398	48.4	35.0	34.[illegible]	35.3	404	394	394	38640	41760	15720	0.93	13200	12600	12840	59952	23712	44640	41160
12.47	60.6	420	48.3	34.9	34.[illegible]	35.2	428	418	414	40560	43920	16920	0.92	13800	13320	13440	64476	25608	44640	41160
12.51	60.6	410	48.4	34.9	34.[illegible]	35.2	422	404	406	39480	42960	16680	0.92	13560	12840	13080	67092	26688	44640	41160
12.55	60.6	400	48.1	34.9	34.[illegible]	35.3	404	396	398	38400	41760	16440	0.92	13080	12600	12840	69684	27780	44640	41160
13.02	61.2	396	48.9	35.2	34.[illegible]	35.5	404	394	392	39000	41760	15120	0.93	13320	12720	12960	74772	29892	44640	41160
13.06	61.2	394	48.9	35.3	35.[illegible]	35.6	406	394	382	38880	41760	15120	0.93	13440	12600	12960	77388	30900	44640	41160
13.10	61.2	392	48.8	35.3	34.[illegible]	35.6	398	390	386	38520	41400	15240	0.93	13200	12600	12720	79920	31908	44640	41160
13.17	61.2	396	49.0	35.2	34.[illegible]	35.6	406	394	386	39000	41760	15120	0.93	13320	12840	12840	83832	33444	44640	41160
13.21	61.2	402	48.8	35.2	34.[illegible]	35.5	410	398	396	39480	42360	15480	0.93	13440	12840	13080	86412	34452	44640	41160
13.25	60.6	386	48.9	35.2	34.7	35.5	394	384	382	37920	40580	14880	0.93	12960	12360	12600	88968	35460	44640	41160
13.32	61.2	380	49.4	35.3	34.9	35.6	388	376	374	38040	40200	12840	0.95	13080	12360	12600	93360	37032	44640	41160
13.36	61.2	384	49.9	35.3	34.9	35.5	392	382	378	38520	40560	12600	0.95	13200	12600	12840	95916	37860	44640	41160

Date 13/12/96

Time	kV_{L-L}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
13.40	60.6	378	50.2	35.2	34.7	35.5	386	376	374	38040	39840	12000	0.95	12960	12360	12600	98484	38688	44640	41160
13.47	61.2	384	49.5	35.4	35.0	35.7	394	382	380	38640	40800	13200	0.95	13200	12600	12840	102972	40152	44640	41160
13.51	61.8	384	49.1	35.6	35.0	35.9	390	380	384	38640	40920	13680	0.94	13080	12600	12960	105552	41[illegible]52	44640	41160
13.55	61.2	382	49.0	35.5	35.1	35.8	388	380	378	38280	40680	13680	0.94	13080	12480	12720	108132	41964	44640	41160
14.02	61.2	382	48.8	35.2	34.8	35.6	388	380	378	37920	40200	13680	0.94	12840	12360	12600	113160	43764	44640	41160
14.06	61.2	386	49.1	35.3	34.9	35.6	394	384	382	38760	40920	13320	0.95	13200	12600	12840	115728	44688	44640	41160
14.10	61.2	388	49.4	35.5	35.0	35.8	396	386	384	39000	41280	13440	0.95	13320	12720	12960	118332	45576	44640	41160
14.17	61.2	390	49.7	35.3	34.9	35.6	396	388	388	39240	41280	12840	0.95	13320	12840	13080	122256	46920	44640	41160
14.21	61.8	324	49.7	35.7	35.2	36.0	328	320	322	33360	34560	8832	0.97	11340	10884	11184	124752	47688	44640	41160
14.25	61.8	324	49.3	35.7	35.2	36.0	328	320	324	33360	34680	9408	0.96	11292	10836	11196	126972	48288	44640	41160
14.32	61.2	320	48.4	35.3	34.9	35.6	326	316	316	32280	33840	10248	0.95	11004	10500	10728	130788	49440	44640	41160
14:36	61.2	320	48.4	35.3	34.8	35.6	324	318	320	32280	33840	10164	0.95	10944	10524	10824	132948	50124	44640	41160
14.40	60.6	322	48.3	35.2	34.7	35.5	326	318	320	32280	33840	10320	0.95	10932	10488	10788	135096	50808	44640	41160
14.47	60.6	334	48.6	35.1	34.7	35.4	342	332	332	33360	35160	11124	0.95	11400	10872	11124	138960	52104	44640	41160
14.51	60.6	332	48.1	35.2	34.7	35.5	338	328	328	32760	34920	11832	0.94	11208	10656	10932	141180	52872	44640	41160
14.55	61.2	332	48.0	35.2	34.8	35.5	340	330	328	33000	35160	12120	0.94	11280	10740	10920	143364	53664	44640	41160
15.02	61.8	340	48.8	35.6	35.2	36.0	348	338	336	34440	36360	11400	0.95	11784	11232	11448	147828	55212	44640	41160
15.06	61.8	338	48.8	35.7	35.3	36.0	346	336	334	34440	36240	11256	0.95	11772	11208	11412	150120	55968	44640	41160
15.10	61.8	342	49.2	35.8	35.4	36.2	348	338	338	35040	36600	10848	0.96	11940	11412	11652	152448	56712	44640	41160
15.17	61.8	342	49.3	35.8	35.4	36.1	348	340	336	35040	36600	10668	0.96	11976	11460	11592	155952	57780	44640	41160
15.21	61.8	340	49.2	35.9	35.4	36.2	346	338	338	34920	36600	10776	0.96	11856	11436	11664	158232	58476	44640	41160
15.25	61.8	340	49.3	35.8	35.3	36.1	346	336	336	34920	36480	10620	0.96	11904	11364	11616	160620	59208	44640	41160
15.32	61.8	342	49.4	35.8	35.4	36.2	348	340	340	35160	36720	10584	0.96	11928	11508	11712	164736	60456	44640	41160
15.3[illegible]	62.4	304	49.2	35.9	35.6	36.2	312	304	300	31560	32880	9192	0.96	10776	10320	10416	167040	61140	44640	41160
15.40	62.4	294	48.9	36.0	35.6	36.3	300	292	288	30360	31680	8844	0.96	10392	9948	10056	169080	61740	44640	41160
15.47	62.4	298	49.0	36.0	35.6	36.4	304	296	294	30840	32160	9012	0.96	10524	10116	10200	172680	62808	44640	41160
15.51	61.8	298	48.9	35.8	35.4	36.1	302	296	294	30600	31920	8736	0.96	10428	10020	10188	174708	63384	44640	41160
15.55	61.8	294	48.8	35.8	35.4	36.1	300	292	290	30360	31560	8772	0.96	10332	9900	10068	176760	63972	44640	41160
16.02	61.8	292	48.5	35.6	35.2	36.0	298	290	288	29880	31200	8988	0.96	10236	9756	9912	180720	65124	44640	41160
16.06	61.2	292	48.2	35.5	35.1	35.8	298	290	288	29640	31080	9240	0.96	10128	9684	9852	182700	65736	44640	41160
16:10	61.2	294	48.3	35.5	35.1	35.8	300	290	290	29760	31200	9276	0.96	10200	9708	9888	184692	66360	44640	41160
16:17	61.2	300	48.3	35.3	35.0	35.8	306	298	296	30360	31800	9576	0.95	10344	9924	10080	187728	67308	44640	41160

Appendix - 3/4 Contd..

Date 13/12/96

Time	kV_{LL}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
16 21	61 2	294	48 0	35 3	35 0	35 7	300	292	292	29640	31200	9888	0 95	10092	9648	9852	189720	67968	44640	41160
16 25	61 2	302	48 3	35 4	35 0	35 7	308	298	296	30240	31920	10344	0.95	10356	9852	10020	191712	68640	44640	41160
16 32	61 8	314	49 4	35 9	35 5	36 2	320	312	310	32160	33720	10008	0 96	10980	10536	10692	195348	69816	44640	41160
16 36	62 4	316	49 4	35 9	35 5	36 2	322	314	312	32520	33960	10116	0.96	11100	10608	10752	197508	70488	44640	41160
16·40	61 8	326	49 0	35 7	35 3	36 1	332	324	322	33120	34920	10932	0.95	11280	10884	10992	199704	71196	44640	41160
16 47	61 2	388	48 5	35 2	34 8	35 5	394	384	384	38280	40800	14280	0 94	12960	12480	12720	203688	72600	44640	41160
16 51	60 6	392	48 1	34 9	34 5	35 2	398	388	388	38160	40920	14640	0.93	13080	12480	12720	206244	73560	44640	41160
16 55	60 6	394	47 9	34 8	34 5	35 2	404	392	390	38280	41160	15360	0.93	13080	12480	12720	208812	74592	44640	41160
17 02	60 6	396	48 6	35 1	34 7	35 5	402	394	390	38880	41640	14760	0.94	13200	12840	12960	213864	76560	44640	41160
17 06	61 2	398	48 8	35 2	34 9	35 6	402	396	394	39360	42000	14880	0 94	13320	12960	13080	216480	77556	44640	41160
17 10	61 2	336	48 6	35 3	35 0	35 8	342	336	332	33480	35640	12240	0.94	11412	10992	11112	219000	78492	44640	41160
17 17	60 6	394	48 6	35 1	34 7	35 5	400	392	388	38520	41400	15120	0 93	13080	12600	12840	222576	79824	44640	41160
17 21	60.6	400	48 3	34 9	34 6	35 3	406	400	394	38880	41880	15480	0.93	13200	12720	12840	225108	80844	44640	41160
17 25	60 6	398	48.0	34 9	34 6	35.3	404	396	392	38280	41640	16200	0.92	13080	12600	12720	227700	81912	44640	41160
17·32	60 6	400	48.3	35 0	34 6	35 3	406	400	394	39000	42000	15600	0.93	13320	12840	12960	232284	83772	44640	41160
17·36	60 6	402	48 2	34 9	34 6	35 2	408	400	396	38760	42120	16320	0 92	13200	12720	12840	234900	84852	44640	41160
17 40	59 9	462	48 2	34 6	34 3	35 0	468	462	456	44040	48000	18840	0.92	15000	14520	14640	237672	86040	44640	41160
17.47	59 8	452	48 1	34.5	34.1	34.9	458	450	448	43200	46800	18120	0.92	14640	14160	14400	242832	88236	44640	41160
17·51	59 9	456	47 9	34 6	34 3	35 0	462	456	452	43680	47400	18480	0.92	14760	14280	14520	245760	89472	44640	41160
17·55	59 9	454	47 9	34 6	34 2	35 0	460	452	450	43440	47160	18360	0.92	14760	14280	14400	248652	90696	45000	41520
18:02	60 0	454	48.4	34.7	34.4	35.2	458	454	450	44040	47400	17520	0.93	14880	14520	14640	254340	93072	45960	42480
18 06	60 6	458	48 8	34 9	34 6	35.3	466	456	452	44760	47880	17040	0.94	15240	14640	14880	257340	94236	46920	43550
18 [illegible]	60.0	450	48 2	34.7	34 3	35 0	458	448	446	43440	46920	17520	0.93	14760	14280	14400	260292	95388	47640	44280
18 [illegible]	60 0	450	47 9	34.7	34.4	[illegible].1	458	448	446	43320	46920	17760	0.93	14760	14160	14400	264660	97176	47640	44280
18 2[illegible]	60 0	450	47.9	34 6	34 3	[illegible].0	458	448	444	43200	46680	17640	0.93	14760	14160	14280	267552	98364	47640	44280
18 25	60.0	450	48.0	34.7	34 4	[illegible].1	460	448	446	43560	47040	17640	0.93	14880	14160	14520	270456	99552	47640	44280
18 32	60.0	452	47.9	34.7	34.4	[illegible].0	460	450	448	43560	47160	18000	0.92	14880	14280	14520	275568	101628	47640	44280
18 36	60.0	454	47 9	34.8	34 4	35.2	462	450	452	43800	47400	18240	0.92	14880	14280	14640	278472	102840	47640	44280
18 40	60 0	458	48 1	34 8	34.4	[illegible].2	464	456	454	44160	47760	18120	0.93	15000	14520	14760	281400	104052	47640	44280
18 47	60.6	480	48.6	34 9	34 4	[illegible] 2	488	476	476	46320	50160	19320	0.92	15720	15120	15480	286692	106272	47640	44280
18 51	60.6	484	48.8	35.0	34.6	[illegible] 3	492	482	476	46920	50640	19080	0.93	16080	15360	15600	289800	107556	47640	44280
18 55	60 6	486	48.9	34.9	34.6	35.3	494	484	480	47160	50880	19080	0.93	16080	15480	15600	292932	108816	48000	44880

Appendix - 3/4 Contd..

Date 13/12/96

Time	kV_{LL}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
19.02	60.6	480	48.6	34.8	34.4	35.2	486	478	476	46440	50160	19080	0.93	15720	15240	15480	299148	111300	48600	45480
19.06	59.8	478	48.1	34.6	34.2	34.9	488	476	472	45720	49560	19320	0.92	15600	15000	15120	302244	112596	49200	46200
19:10	60.0	480	48.3	34.7	34.3	35.0	486	476	476	45960	49920	19320	0.92	15600	15000	15360	305316	113892	49560	46560
19.17	60.0	480	48.4	34.8	34.4	35.1	488	476	476	46200	50040	19200	0.92	15720	15120	15480	309936	115800	49800	46800
19.21	60.6	478	48.3	34.9	34.5	35.2	486	474	474	45960	49920	19440	0.92	15600	15000	15360	313044	117108	49800	46800
19.25	60.0	476	48.1	34.8	34.4	35.1	484	472	472	45720	49680	19320	0.92	15600	14880	15240	316116	118404	49800	46800
19:32	60.0	474	47.9	34.7	34.4	35.1	482	468	472	45360	49440	19800	0.92	15480	14760	15120	321444	120708	49800	46800
19.36	60.6	476	48.1	34.9	34.5	35.2	486	472	472	45840	49800	19560	0.92	15720	14880	15240	324492	122016	49800	46800
19.40	60.6	480	48.6	35.0	34.6	35.2	488	474	474	46440	50160	18960	0.93	15840	15120	15480	327588	123312	49800	46800
19.47	60.6	474	48.3	34.8	34.4	35.2	482	470	472	45720	49560	19080	0.92	15480	14880	15360	333000	125544	49800	46800
19.51	60.0	476	48.0	34.7	34.4	35.1	482	472	472	45480	49560	19560	0.92	15480	14880	15120	336060	126840	49800	46800
19.55	60.6	474	48.2	34.8	34.4	35.2	482	470	472	45600	49560	19440	0.92	15480	14880	15240	339096	128148	49800	46800
20.02	60.6	482	48.7	35.0	34.7	35.4	490	480	476	46920	50760	19200	0.93	15960	15360	15600	345168	130656	49800	46800
20.06	61.2	462	48.9	35.3	34.9	35.6	470	458	458	45480	48840	17880	0.93	15480	14880	15120	348240	131904	49800	46800
20:10	61.2	482	49.0	35.2	34.9	35.6	490	480	476	47520	51000	18480	0.93	16200	15600	15720	351348	133116	49800	46800
20:17	61.2	478	48.8	35.2	34.8	35.6	486	476	474	46920	50520	18720	0.93	15960	15360	15600	356076	134976	49800	46800
20.21	61.2	482	48.9	35.2	34.8	35.6	488	480	480	47520	50880	18360	0.93	16080	15600	15840	359256	136224	49800	46800
20.25	61.2	482	49.0	35.3	34.9	35.6	488	480	478	47520	51000	18480	0.93	16080	15600	15840	362412	137448	49800	46800
20:32	61.2	476	49.2	35.3	34.9	35.7	480	474	474	47040	50400	18240	0.93	15840	15480	15720	367920	139584	49800	47040
20.36	61.2	482	49.5	35.4	34.9	35.8	486	478	482	47880	51120	18000	0.94	16080	15600	16080	371100	140796	49800	47040
20.40	61.2	480	49.9	35.3	34.9	35.6	486	478	478	47640	50880	17640	0.94	16080	15600	15840	374292	141984	49800	47040
20.47	61.2	476	50.1	35.5	35.0	35.8	482	474	474	47640	50640	17400	0.94	16080	15600	15840	379860	144048	50040	47520
20.51	61.2	480	50.3	35.3	35.0	35.8	486	478	476	47880	50880	17160	0.94	16200	15720	15960	383064	145200	50040	47520
20.55	61.2	476	50.2	35.3	34.9	35.8	480	474	476	47520	50520	17040	0.94	16080	15600	15960	386244	146352	50040	47760
21.02	61.8	466	49.4	35.6	35.2	36.0	472	464	464	46680	49800	17520	0.94	15720	15360	15600	392484	148644	50040	47760
21.06	61.8	470	49.6	35.6	35.2	35.9	476	468	466	47040	50160	17400	0.94	15960	15480	15600	395604	149808	50040	47760
21.10	61.2	478	49.6	35.5	35.1	35.8	484	476	474	47760	50880	17400	0.94	16200	15600	15960	398748	150960	50040	47760
21:17	61.2	448	48.5	35.2	34.9	35.6	456	446	444	44280	47400	17040	0.93	15120	14520	14640	403356	152700	50040	47760
21:21	60.6	448	48.4	35.2	34.8	35.5	456	444	444	43920	47160	17280	0.93	15000	14400	14640	406284	153852	50040	47760
21.25	61.2	450	48.7	35.3	34.9	35.6	458	448	448	44640	47760	16920	0.94	15120	14640	14880	409212	154992	50040	47760
21.32	61.2	450	48.8	35.4	35.0	35.8	456	446	446	44760	47760	16320	0.94	15240	14640	15000	414468	156948	50040	47760
21:36	61.2	444	48.6	35.2	34.8	35.6	448	442	446	43920	47040	16680	0.94	14760	14400	14760	417432	158064	50040	47760

Appendix - 3/4 Contd..

Date 13/12/96

Time	kV_{L-L}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
21 40	61 2	442	48 4	35 2	34 8	35 6	448	438	442	43680	46800	16800	0 93	14760	14280	14640	420348	159180	50040	47760
21 47	61 2	442	48 6	35 4	35 0	35 8	450	440	438	43920	46920	16680	0 94	15000	14400	14640	425484	161148	50040	47760
21 51	61 8	446	49 0	35 6	35 2	35 9	452	442	444	44640	47520	16320	0 94	15120	14640	15000	428436	162240	50040	47760
21 55	61 8	448	49 3	35 7	35 3	36 1	458	446	444	45360	48120	15840	0 94	15480	14880	15120	431448	163320	50040	47760
22 02	61 8	446	49 2	35 8	35 3	36 1	452	442	446	45120	47880	16080	0 94	15240	14760	15120	437412	165408	50040	47760
22 06	61 8	444	49 0	35 7	35 3	36 1	450	440	440	44640	47520	16320	0 94	15120	14640	14880	440400	166476	50040	47760
22.10	62 4	444	49 1	35 8	35 5	36 2	452	442	440	44880	47760	16320	0 94	15240	14760	14880	443376	167556	50040	47760
22·17	61 8	440	48 8	35 6	35 3	36 0	448	436	436	44040	47040	16560	0 94	15000	14400	14640	447852	169212	50040	47760
22 21	61 8	440	48 7	35.7	35 2	36 0	446	434	438	43920	47040	16560	0 94	14880	14280	14760	450804	170316	50040	47760
22.25	61 8	440	48 6	35 6	35 2	36.0	444	436	438	43800	46920	16920	0 93	14760	14400	14640	453744	171420	50040	47760
22 32	61 2	442	48 3	35 5	35 1	35 8	448	438	438	43680	46920	17160	0 93	14880	14280	14640	458868	173412	50040	47760
22 36	61 2	454	48 4	35 4	35 0	35 8	462	448	450	44400	48120	18600	0.92	15120	14520	14760	461808	174600	50040	47760
22:40	61 2	464	48 5	35 4	35 0	35 8	470	462	462	45720	49320	18600	0.93	15480	15000	15240	464868	175872	50040	47760
22.47	61 8	470	48 7	35 5	35 2	35 9	478	470	464	46440	50160	18960	0.93	15840	15240	15360	470280	178080	50040	47760
22.51	61 8	474	48 8	35 6	35 3	36 0	480	472	470	47040	50640	18840	0 93	15960	15360	15600	473400	179328	50040	47760
22 55	61 8	472	49 1	35 8	35 4	36 1	480	468	468	47040	50640	18960	0 93	16080	15360	15600	476544	180588	50040	47760
23.02	62 4	472	49 3	36 0	35 6	36 3	480	468	466	47400	50880	18480	0 93	16200	15480	15720	482832	183048	50040	47760
23 06	62.4	474	49 4	36 0	35 6	36.3	482	470	468	47520	51120	18720	0 93	16200	15600	15720	486012	184296	50040	47760
23 10	62 4	474	49 3	36 0	35 6	36 4	484	472	470	47760	51240	18720	0.93	16320	15600	15840	489180	185544	50040	47760
23·17	62 4	446	49 6	36 2	35 8	36 5	450	442	446	45360	48360	16800	0 94	15360	14880	15240	493884	187356	50280	47760
23.21	63 0	436	49 4	36 3	36 0	36 7	444	434	430	44520	47520	16680	0 94	15120	14520	14760	496908	1884[illegible]	50280	47760
23.25	63.0	434	49 3	36 4	36 0	36.7	440	430	430	44160	47160	16800	0 94	15000	14400	14760	499872	1896[illegible]	50280	47760
23:32	63.0	426	48 8	36 2	35.9	36.5	436	424	420	43200	46320	16800	0.93	14760	14040	14400	5049[illegible]	1915[illegible]	50280	47760
23 36	63 0	426	48 9	36.2	35 9	36.5	436	422	420	43200	46320	16680	0.93	14760	14040	14400	50785[illegible]	1926[illegible]	50280	47760
23:40	62.4	442	49 0	36 2	35 8	36 5	448	440	436	44520	47880	17640	0.93	15120	14640	14760	510804	1938[illegible]	50280	47760
23:47	63.0	446	49.6	36 3	35.9	36.7	452	444	444	45480	48600	17280	0.94	15360	14880	15240	516096	1959[illegible]	50280	47760
23:51	63.0	446	49.6	36.3	35.9	36.6	454	442	440	45240	48480	17160	0.94	15480	14760	15000	519120	197040	50280	47760
23:55	63.0	444	49.1	36.2	35.8	36.5	452	442	442	45000	48240	17520	0.93	15360	14760	15000	522144	198192	50280	47760

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Appendix - 3/4 Contd..

Time	kV_{LL}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
0.02	62.4	438	48.8	36.2	35.8	36.5	446	434	434	44040	47520	17520	0.93	15000	14400	14640	528000	200496	50280	47760
0.06	62.4	434	48.3	35.9	35.5	[illegible]	438	430	432	43200	46680	17880	0.92	14520	14160	14520	530916	201684	50280	47760
0.10	61.8	434	48.1	35.8	35.3	[illegible]	442	432	432	43080	46560	17880	0.92	14640	14040	14280	533796	202872	50280	47760
0.17	62.4	438	48.5	35.9	35.6	[illegible]	446	432	434	43680	47160	17640	0.93	14880	14280	14640	538140	204648	50280	47760
0.21	62.4	440	48.6	35.9	35.6	[illegible]	446	438	436	44040	47400	17520	0.93	15000	14400	14640	541104	205836	50280	47760
0.25	62.4	440	48.5	36.0	35.6	[illegible]	446	436	438	44040	47520	17760	0.93	15000	14400	14760	544044	207024	50280	47760
0.32	62.4	438	48.4	35.9	35.5	36.2	444	434	432	43560	47040	17640	0.93	14880	14280	14520	549204	[illegible]	50280	47760
0.36	61.8	440	48.4	35.8	35.5	36.2	448	436	438	43920	47280	17760	0.93	14880	14280	14640	[illegible]	[illegible]	50280	47760
0.40	61.8	444	48.4	35.8	35.4	36.1	450	438	450	44280	47760	17760	0.93	15240	14400	14640	555060	[illegible]	50280	47760
0.47	61.8	436	48.2	35.8	35.4	36.1	442	432	432	43200	46680	17760	0.93	14640	14160	14400	[illegible]	[illegible]	50280	47760
0.51	62.4	434	48.3	35.9	35.6	36.2	442	432	428	43080	46680	18000	0.92	14640	14160	14280	[illegible]	[illegible]	50280	47760
0.55	62.4	438	48.8	36.0	35.7	36.4	446	436	432	44040	47400	17400	0.93	15000	14400	14640	[illegible]	[illegible]	50280	47760
1.02	63.0	440	49.1	36.3	35.9	36.7	448	440	436	44760	48000	17160	0.93	15240	14760	14880	[illegible]	[illegible]	50280	47760
1.06	63.0	442	49.3	36.3	35.9	36.7	450	438	436	45000	48120	17040	0.94	15360	14760	15000	[illegible]	[illegible]	50280	47760
1.10	63.0	450	49.4	36.2	35.9	36.6	458	448	446	45960	48960	16920	0.94	15600	15000	15240	[illegible]	[illegible]	50280	47760
1.17	63.0	454	49.6	36.2	35.9	36.6	462	452	448	46320	49320	17040	0.94	15720	[illegible]	15360	[illegible]	[illegible]	50280	47760
1.21	63.0	442	49.7	36.3	35.9	36.6	450	440	436	45000	48000	16800	0.94	15360	[illegible]	15000	[illegible]	223308	50280	47760
1.25	63.0	444	49.8	36.2	35.8	36.5	454	442	438	45360	48240	16560	0.94	15480	[illegible]	15000	[illegible]	224412	50280	47760
1.32	63.0	446	49.9	36.3	35.9	36.6	454	442	442	45720	48600	16440	0.94	15600	[illegible]	15240	593892	[illegible]	50280	47760
1.36	63.0	446	49.9	36.4	36.0	36.7	456	444	440	45840	48600	16320	0.94	15720	15000	15120	596964	[illegible]	50280	47760
1.40	63.0	444	49.9	36.2	35.8	36.5	454	442	438	45480	48240	16320	0.94	15480	14880	15000	600012	[illegible]	50280	47760
1.47	63.0	434	49.5	36.4	36.1	36.8	442	432	428	44760	47520	15840	0.94	15240	14640	14880	605340	[illegible]	50280	47760
1.51	63.0	432	49.5	36.4	36.1	36.8	442	430	426	44520	47280	15600	0.94	15240	14640	14760	608328	[illegible]	50280	47760
1.55	63.0	430	49.7	36.4	36.1	36.7	440	428	424	44280	46920	15360	0.95	15120	14520	14640	611292	[illegible]	50280	47760
2.02	63.0	426	50.0	36.5	36.1	36.8	436	424	422	44280	46680	14760	0.95	15120	14520	14760	617112	[illegible]	50280	47760
2.06	63.0	430	50.1	36.4	36.1	36.8	438	428	422	44520	46920	14880	0.95	15240	14640	14640	620076	[illegible]	50280	47760
2.10	63.6	426	49.8	36.5	36.2	36.9	434	428	418	44280	46800	15000	0.95	15120	14640	14640	623040	[illegible]	50280	47760
[illegible]	63.0	424	49.8	36.5	36.2	36.8	432	424	418	44040	46560	15000	0.95	15000	14520	14520	627492	[illegible]	50280	47760
[illegible]	63.6	428	49.9	36.5	36.2	36.9	436	426	422	44280	46800	15000	0.95	15120	14520	14760	630468	[illegible]	50280	47760
[illegible]	63.0	426	49.9	36.5	36.1	36.8	434	422	420	44160	46560	14760	0.95	15120	14520	14640	633396	240012	50280	47760
[illegible]	63.0	426	49.8	36.5	36.1	36.8	434	426	422	44280	46680	14880	0.95	15120	14520	14760	638604	241764	50280	47760

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Date 14/12/96

Time	kV_{LL}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
2 36	63 0	440	50 0	36 4	35 9	36 7	448	438	436	45360	48000	15840	0 94	15480	14880	15000	641592	242796	50280	47760
2 40	63 0	454	49 9	36 3	35 9	36 6	460	454	450	46560	49440	16800	0 94	15840	15240	15480	644640	243876	50280	47760
2 47	63 0	468	50 0	36 2	35 9	36 5	476	466	464	47880	50880	17160	0 94	16320	15720	15960	650184	245880	50280	47760
2 51	62 4	468	50 0	36 2	35 8	36 5	476	466	462	47760	50760	17040	0 94	16320	15720	15840	653388	247044	50280	47760
2.55	63 0	468	50 0	36 2	35 8	36 5	474	464	462	47640	50760	17280	0 94	16200	15600	15840	656580	248184	50280	47760
· 3.02	63 0	466	49 7	36 3	35 9	36 7	472	466	460	47760	50760	17400	0 94	16200	15720	15840	662844	250452	50280	47760
3 06	63 0	468	49 8	36 3	35 9	36 7	472	464	464	47760	50760	17280	0 94	16200	15720	15960	666048	251616	50280	47760
3.10	63 0	468	49 8	36 2	35 9	36 5	476	466	462	47760	50880	17280	0 94	16320	15720	15840	669216	252756	50280	47880
3 17	63 0	466	49 8	36 2	35 9	36.5	474	464	460	47520	50640	17280	0 94	16200	15600	15840	673992	254496	50280	48000
3 21	63 0	466	49 9	36 2	35 8	36 6	472	464	462	47640	50520	17040	0.94	16080	15600	15840	677160	255636	50280	48000
3 25	62.4	464	50 1	36 1	35 8	36 5	470	462	460	47400	50280	16920	0 94	16080	15480	15720	680376	256776	50280	48000
3.32	63 0	404	50 4	36 4	36 0	36 7	408	402	398	41760	44040	13800	0 95	14160	13800	13920	685308	258420	50280	48000
3.36	63.0	404	50 5	36 5	36 1	36 8	408	402	400	42000	44160	13680	0 95	14280	13800	14040	688104	259344	50280	48000
3 40	63 0	390	50 3	36 5	36.1	36.8	396	388	386	40560	42720	13680	0 95	13800	13320	13440	690876	260256	50280	48000
3 47	63 0	390	50 3	36 5	36 1	36.8	394	390	388	40560	42720	13560	0 95	13680	13320	13560	695592	261816	50280	48000
3.51	63 0	400	50 3	36 5	36 1	36 8	404	398	396	41520	43680	13680	0.95	14040	13680	13800	698352	262728	50280	48000
3 55	63.0	398	50 2	36.4	36.1	36.8	404	398	394	41280	43560	13920	0 95	14040	13560	13680	701136	263652	50280	48000
4 02	63 0	402	50 5	36 4	36 0	36.8	406	400	398	41640	43800	13800	0.95	14040	13680	13920	706608	265464	50280	48000
4·06	63.0	404	50 5	36 5	36 1	36 8	410	402	396	41880	44160	13800	[illegible]	14280	13800	13800	709368	266376	50280	48000
4 10	63 0	402	50.4	36.5	36 1	36 8	410	400	396	41760	44040	13800	[illegible]	14280	13680	13800	712176	267300	50280	48000
4·17	63 6	400	50 6	36.6	36 2	36.9	408	400	394	41880	43920	13440	[illegible]	14280	13800	13800	716376	[illegible]	50280	48000
4:21	63 0	400	50 5	36.5	36.2	36.8	408	400	394	41760	43920	13680	[illegible]	14280	13680	13800	719172	[illegible]	50280	48000
4.25	63.0	402	50 4	36 5	36 1	36 8	408	400	396	41760	43920	[illegible]	0 95	14160	13680	13800	721968	[illegible]	50280	48000
4 32	63 0	402	50 3	36.5	36 1	36 8	408	402	398	41880	44040	[illegible]	0 95	14160	13800	13920	726864	[illegible]	50280	48000
4:36	63.6	398	50 3	36.5	36 2	36.9	404	396	392	41400	43560	[illegible]	0 95	14040	13560	13680	729636	273048	50280	48000
4:40	63.0	402	50.0	36.5	36.2	36.8	410	400	396	41760	44040	13920	0 95	14280	13680	13800	732420	273972	50280	48000
4·47	63.0	456	49.7	36 2	35 9	36.5	466	456	450	46800	49680	[illegible]	0 94	15960	15360	15480	737796	275868	50280	48000
4·51	63.0	444	49.8	36.3	35 9	36.6	452	442	438	45720	48360	15840	0 95	15600	15000	15120	740844	276936	50280	48000
4.55	63.0	446	49.7	36.3	35.9	36.6	454	444	442	45960	48600	15960	0 95	15600	15000	15240	743904	278004	50280	48000
5:02	63.0	442	49 4	36 4	36 0	36 7	450	440	436	45480	48240	16080	0 94	15480	14880	15000	749892	280092	50280	48000
5 06	63.0	442	49 4	36.3	36 0	36.7	450	440	436	45360	48120	15840	0 94	15480	14880	15120	752940	281160	50280	48000
5:10	63.0	438	49.4	36.3	36.0	36.7	446	436	432	45120	47760	15720	0 94	15360	14760	15000	755964	282216	50280	48000

Appendix - 3/4 Contd..

Date : 14/12/96

Time	kV_{L-L}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
5.17	63.0	444	49.5	36.3	36.0	36.7	452	442	436	45600	48360	15840	0.95	15600	15000	15120	760500	[illegible]	50280	48000
5.21	63.0	442	49.5	36.3	36.0	36.7	450	440	436	45480	48120	15720	0.95	15480	14880	15000	763536	[illegible]	50280	48000
5.25	63.0	442	49.4	36.3	35.9	36.6	448	440	436	45360	48000	15840	0.94	15480	14880	15000	766560	[illegible]	50280	48000
5.32	63.0	434	49.3	36.2	35.9	36.6	442	434	430	44640	47280	15600	0.94	15120	14640	14880	771840	[illegible]	50280	48000
5.36	63.0	392	49.2	36.5	36.1	36.8	400	390	388	40800	42840	12960	0.95	13920	13320	13560	774708	[illegible]	50280	48000
5.40	63.0	388	49.0	36.4	36.0	36.7	396	386	384	40200	42240	12960	0.95	13680	13200	13320	777432	[illegible]	50280	48000
5.47	62.4	384	48.6	36.2	35.8	36.5	390	380	378	39480	41520	13080	0.95	13440	12840	13080	782112	[illegible]	50280	48000
5.51	63.0	382	48.6	36.2	35.9	36.6	390	380	378	39480	41520	12840	0.95	13440	12960	13080	784728	291924	50280	48000
5.55	63.0	382	48.6	36.2	35.9	36.5	388	380	376	39240	41400	13080	0.95	13440	12840	12960	787380	292812	50280	48000
6.02	63.0	390	49.1	36.5	36.1	36.8	396	386	386	40560	42600	12840	0.95	13800	13200	13560	792636	294504	50280	48000
6.06	63.0	392	49.6	36.5	36.2	36.8	400	390	386	41040	42960	12480	0.96	14040	13440	13680	795372	295344	50280	48000
6.10	63.0	394	49.9	36.5	36.1	36.8	400	392	390	41280	42960	12000	0.9[illegible]	14040	13560	13680	798108	296148	50280	48000
6.17	63.0	388	49.5	36.4	36.1	36.8	394	386	384	40680	42480	12120	0.9[illegible]	13800	13320	13560	802236	297384	50280	48000
6.21	63.0	390	49.4	36.4	36.1	36.8	398	388	384	40800	42600	12120	0.[illegible]	13920	13320	13560	804960	298200	50280	48000
6.25	63.0	390	49.1	36.3	35.9	36.7	398	388	386	40560	42480	12600	0.96	13800	13320	13560	807672	299028	50280	48000
6.32	62.4	388	48.5	35.9	35.6	36.2	396	386	382	39600	41760	13320	0.95	13440	12960	13080	812388	300528	50280	48000
6.36	61.8	392	48.3	35.7	35.3	36.1	396	388	390	39600	41880	13560	0.95	13440	12960	13320	815028	301428	50280	48000
6.40	61.8	394	48.1	35.5	35.2	35.9	400	390	390	39600	42000	13800	0.94	13440	12960	13200	817668	302352	50280	48000
6.47	61.8	410	48.4	35.5	35.1	35.9	418	408	408	40680	43800	16080	0.93	13800	13320	13680	822324	304020	50280	48000
6.51	61.2	410	48.2	35.5	35.0	35.8	418	406	406	40800	43560	15120	0.94	13920	13320	13560	825048	305028	50280	48000
6.55	61.2	412	47.9	35.4	35.0	35.8	420	408	408	40800	43800	15840	0.93	13920	13320	13560	827772	306072	50280	48000
7.02	61.2	466	48.4	35.2	34.8	35.5	476	462	462	45600	49200	18360	0.93	15600	14880	15240	833568	308352	50280	48000
7.06	60.6	466	48.0	35.0	34.7	35.4	474	462	462	45240	48960	18840	0.92	15360	14760	15120	836592	309588	50280	48000
7.10	60.6	466	48.3	35.0	34.7	35.4	472	464	460	45120	48840	18600	0.92	15360	14880	15000	839592	310836	50280	48000
7.17	61.2	470	48.6	35.2	34.9	35.6	478	468	464	46200	49680	18480	0.93	15720	15120	15360	844260	312684	50280	48000
7.21	60.6	466	47.9	35.0	34.6	35.3	472	462	462	45000	48840	18720	0.92	15360	14760	15000	847320	313920	50280	48000
7.25	60.6	428	48.0	35.1	34.7	35.4	436	424	424	41520	45120	17760	0.92	14160	13560	13800	850284	315156	50280	48000
7:32	60.6	430	48.0	35.0	34.7	35.5	438	428	424	41640	45240	17640	0.92	14280	13680	13800	855144	317208	50280	48000
7:36	60.6	432	48.3	35.1	34.7	35.5	438	430	428	42120	45600	17400	0.92	14280	13800	14040	857940	318372	50280	48000
7:40	60.6	428	48.3	35.0	34.7	35.5	436	426	424	41760	45120	17160	0.93	14280	13680	13920	860736	319536	50280	48000
7.47	61.2	352	47.9	35.4	35.0	35.8	356	348	348	34440	37200	14040	0.93	11712	11244	11520	865212	321348	50280	48000
7.51	61.2	350	47.9	35.2	34.8	35.6	356	348	348	34320	36960	13920	0.93	11652	11172	11436	867504	322284	50280	48000

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Appendix - 3/4 Contd..

Date 14/12/96

Time	kV_{L-L}	AMPS	Hz	kV(R)	kV(Y)	kV(B)	I(R)	I(Y)	(B)	kW	kVA	kVAR	Pf	kW(R)	kW(Y)	kW(B)	kWh	kVARh	kVA Peak	kW Peak
7 55	61 2	350	48 2	35 2	34 7	35 5	356	348	348	34440	36960	13560	0 93	11700	11232	11520	869796	323208	50280	48000
8 02	61 2	348	48 5	35 4	35.1	35 8	354	346	346	34680	37080	13080	0 94	11784	11340	11532	874368	324960	50280	48000
8 06	61 8	352	48 7	35 6	35 2	35 9	358	350	348	35280	37560	12840	0 94	11976	11532	11760	876708	325824	50280	48000
8 10	61 8	358	48 6	35 5	35 2	35.9	364	354	352	35760	38040	13080	0 94	12120	11676	11856	879072	326676	50280	48000
8 17	61 2	356	48 6	35 4	34 9	35 7	362	354	354	35640	37800	12600	0 94	12120	11628	11856	882612	327960	50280	48000
8 21	61 2	352	48 6	35 4	35.0	35 8	360	350	350	35280	37440	12360	0 94	12000	11544	11760	885012	328800	50280	48000
8·25	61 2	352	48 3	35 2	34 8	35 6	358	348	348	34920	37080	12600	0 94	11856	11388	11628	887352	329628	50280	48000
8 32	60 6	352	48 1	35 2	34 7	35 5	358	348	350	34680	37080	13200	0.94	11784	11304	11580	891432	331128	50280	48000
8 36	61 2	296	47 9	35 3	35 0	35 7	302	296	292	29520	31440	10956	0.94	10032	9660	9768	893700	332016	50280	48000
8·40	61 2	296	48 0	35 3	35.0	35 6	302	294	292	29520	31440	10776	0 94	10068	9624	9804	895668	332736	50280	48000
8 47	61 2	296	48.4	35.3	35 0	35 7	300	294	292	29640	31320	10308	0 94	10068	9696	9816	899124	333972	50280	48000
8 51	61 2	294	48 3	35 3	34 9	35 6	302	292	290	29520	31200	10200	0.95	10092	9636	9780	901068	334644	50280	48000
8.55	61 2	296	48 2	35 3	34 9	35 6	302	294	292	29520	31320	10356	0 94	10092	9624	9828	903048	335340	50280	48000
9 02	61 2	294	48.0	35.2	34 8	35.6	300	292	292	29280	31080	10428	0.94	9984	9552	9744	906948	336684	50280	48000
9 06	61 2	294	48 2	35 3	34 9	35 6	300	292	290	29400	31080	10152	0 95	10068	9588	9720	908904	337392	50280	48000
9·10	61 2	298	48 7	35 5	35 2	35 8	304	296	294	30120	31680	9948	0.95	10284	9864	9972	910884	338052	50280	48000
9.17	61 8	268	48.7	35.5	35 2	35 8	274	266	264	27120	28560	8760	0 95	9348	8832	9000	913776	338964	50280	48000
9·21	61 2	278	48 6	35.3	34 9	35 6	282	274	274	27720	29280	9504	0 95	9492	9036	9216	915624	339588	50280	48000
9 25	61 2	274	48 6	35.3	35 0	35 6	280	272	270	27360	29040	9672	0 94	9384	8916	9060	917472	340236	50280	48000
9 32	61 2	274	47 9	35 2	34 9	35 6	278	272	270	27000	28920	10296	0 93	9228	8820	8964	920700	341424	50280	48000
9 36	61 2	268	48 6	35 5	35 1	35 8	274	268	264	26880	28560	9468	0.94	9204	8808	8928	922488	342084	50280	48000
9·40	61 8	266	49.1	35.6	35 2	35.9	272	264	264	27000	28440	8868	0.95	9216	878[illegible]	8988	924312	342708	50280	48000
9.47	61.8	254	49 2	35.7	35 3	36 0	262	252	252	26040	27240	8076	0.96	8928	8433	8640	927384	343680	50280	48000
9.51	61.8	242	49.1	35.8	35 3	36 0	248	238	238	24840	25920	7164	0.96	8556	8052	8268	929100	344220	50280	48000
9:55	61 8	234	48 7	35 8	35.3	36.0	240	230	230	24240	25080	6432	0.97	8316	7836	8040	930756	344700	50280	48000
10:02	61 8	220	48 3	35.6	35.2	35.9	228	218	218	22920	23520	5544	0.97	7884	7404	7608	933852	345480	50280	48000

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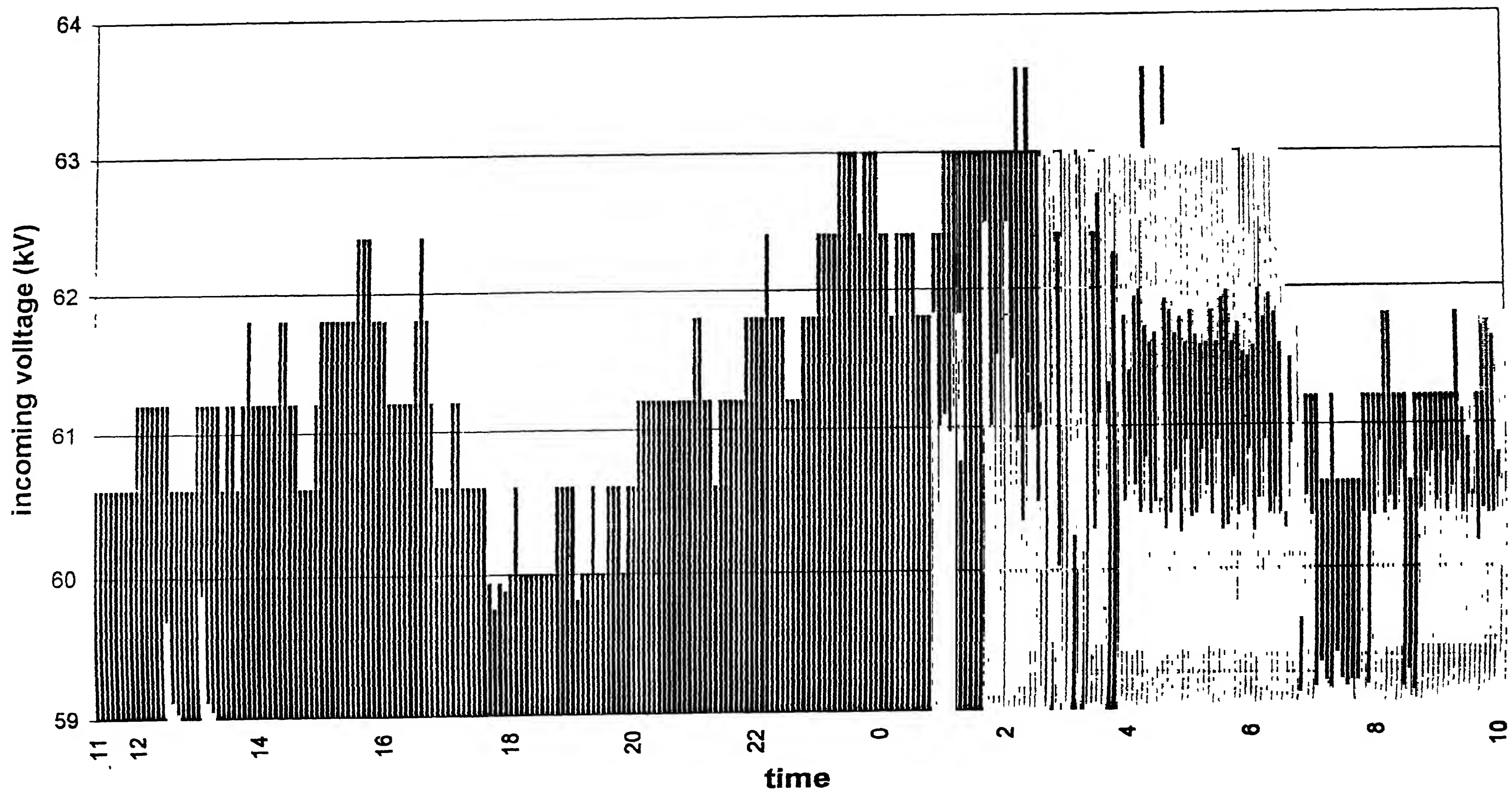
Voltage Profile For a Typical Day



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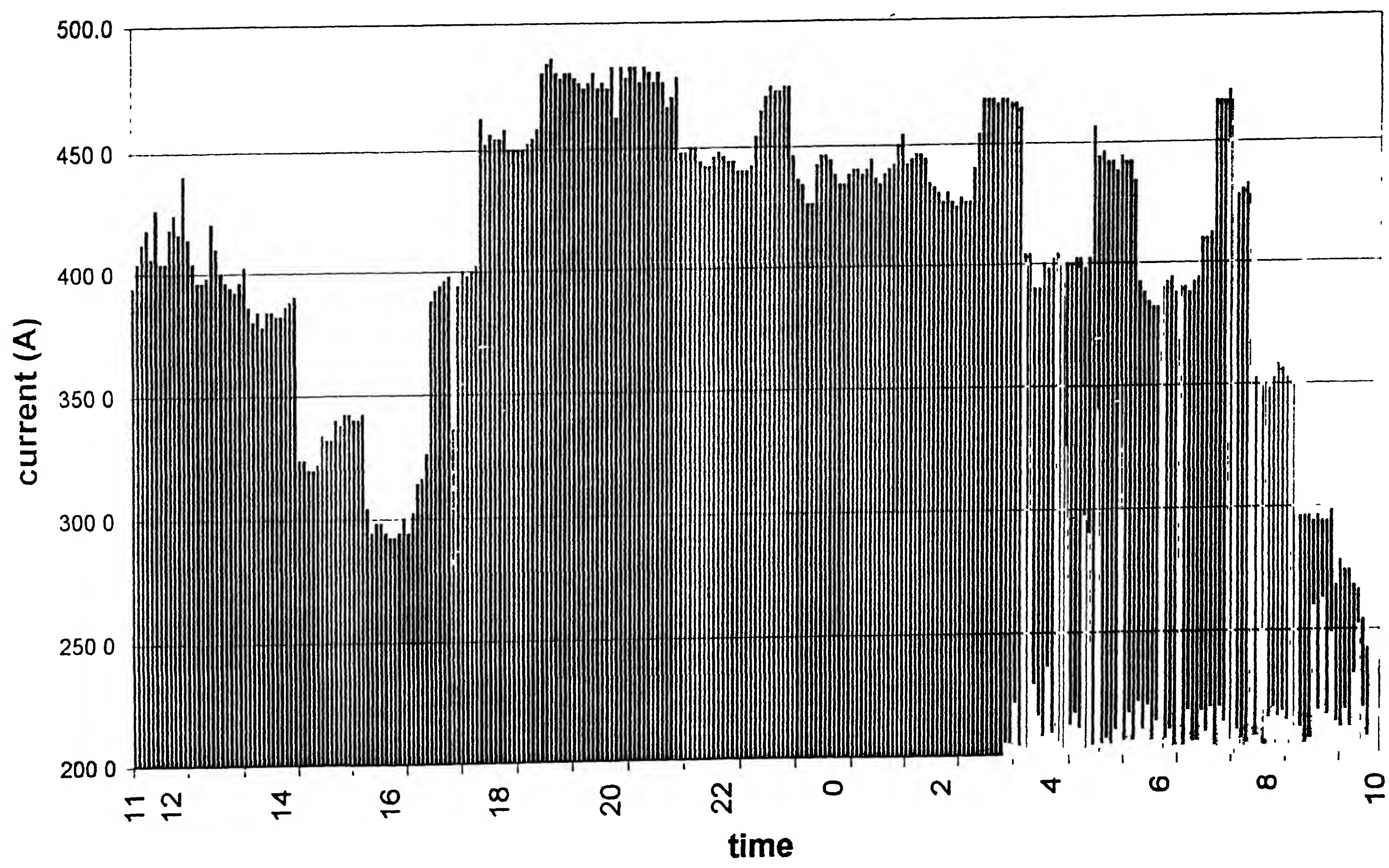
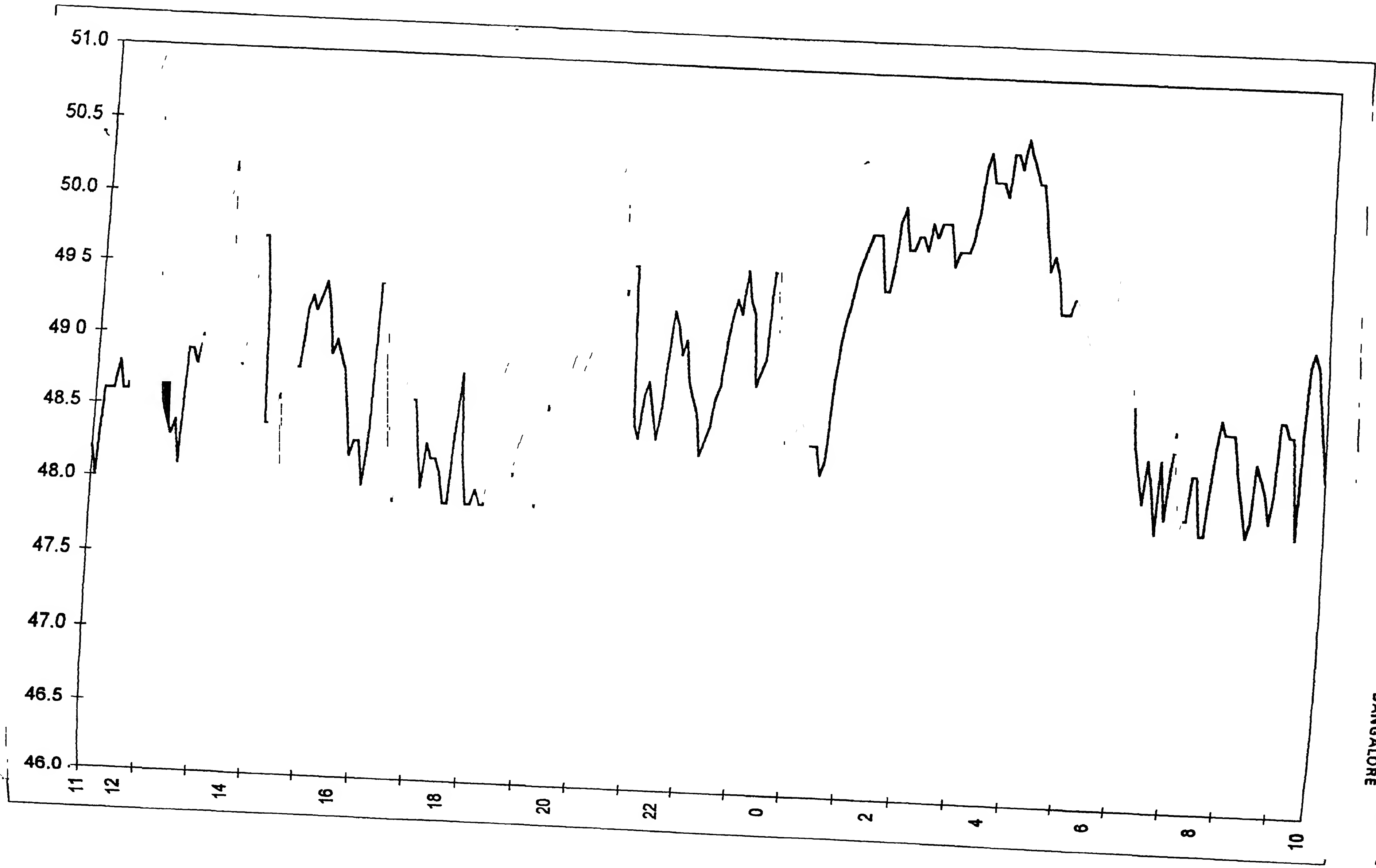
Variation in Load Current



Variation in Frequency



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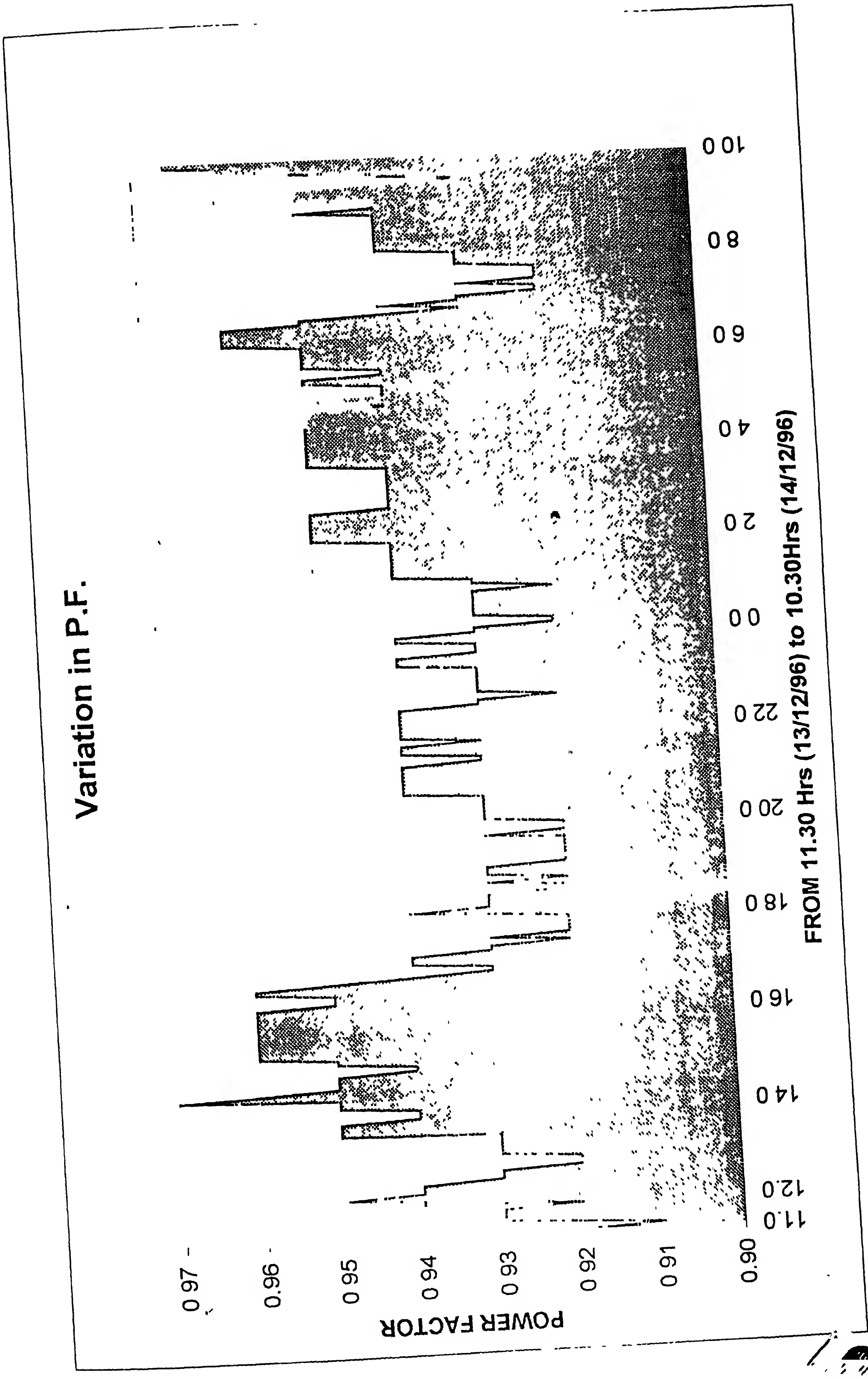
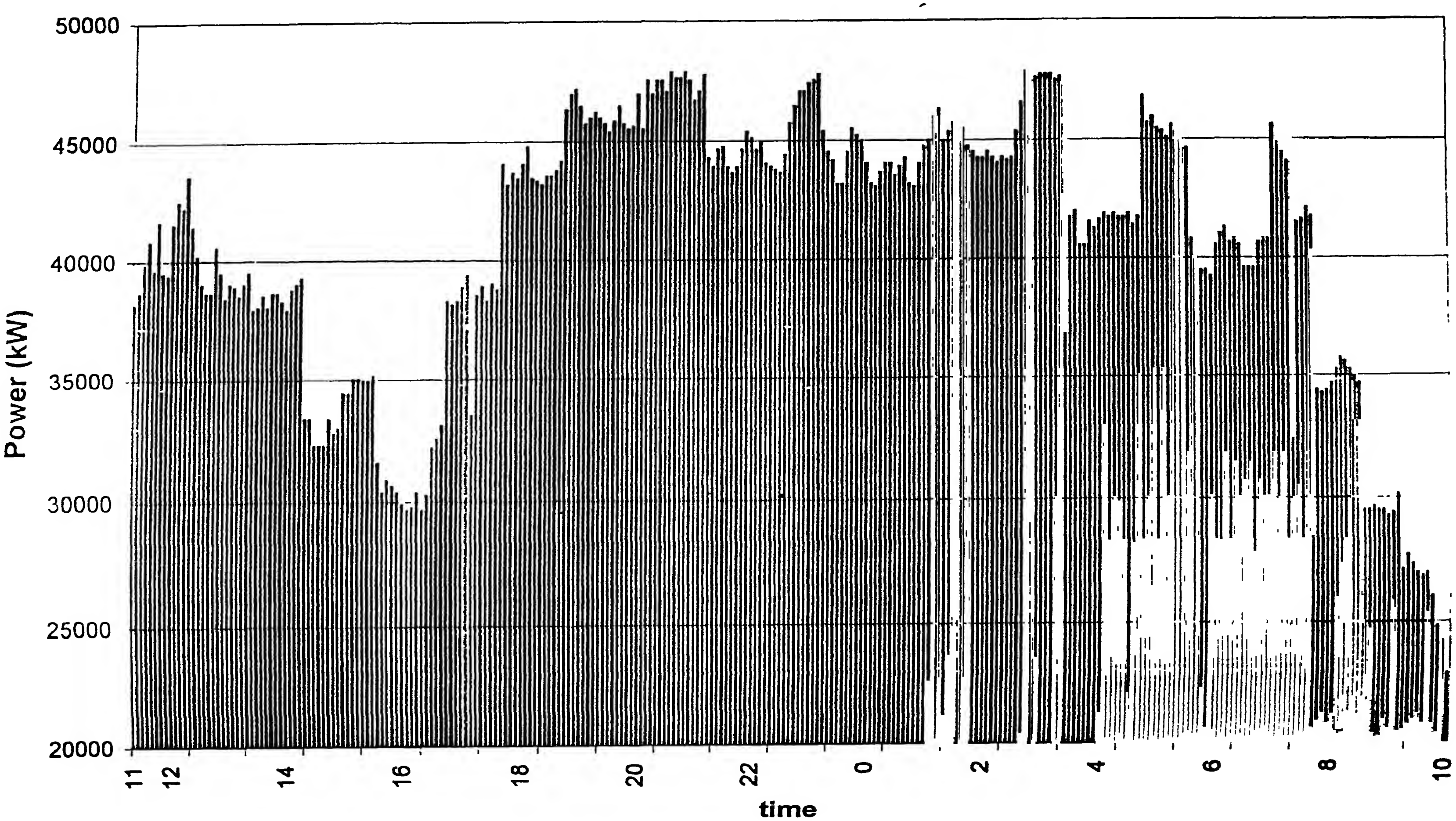


Variation in Power Demand



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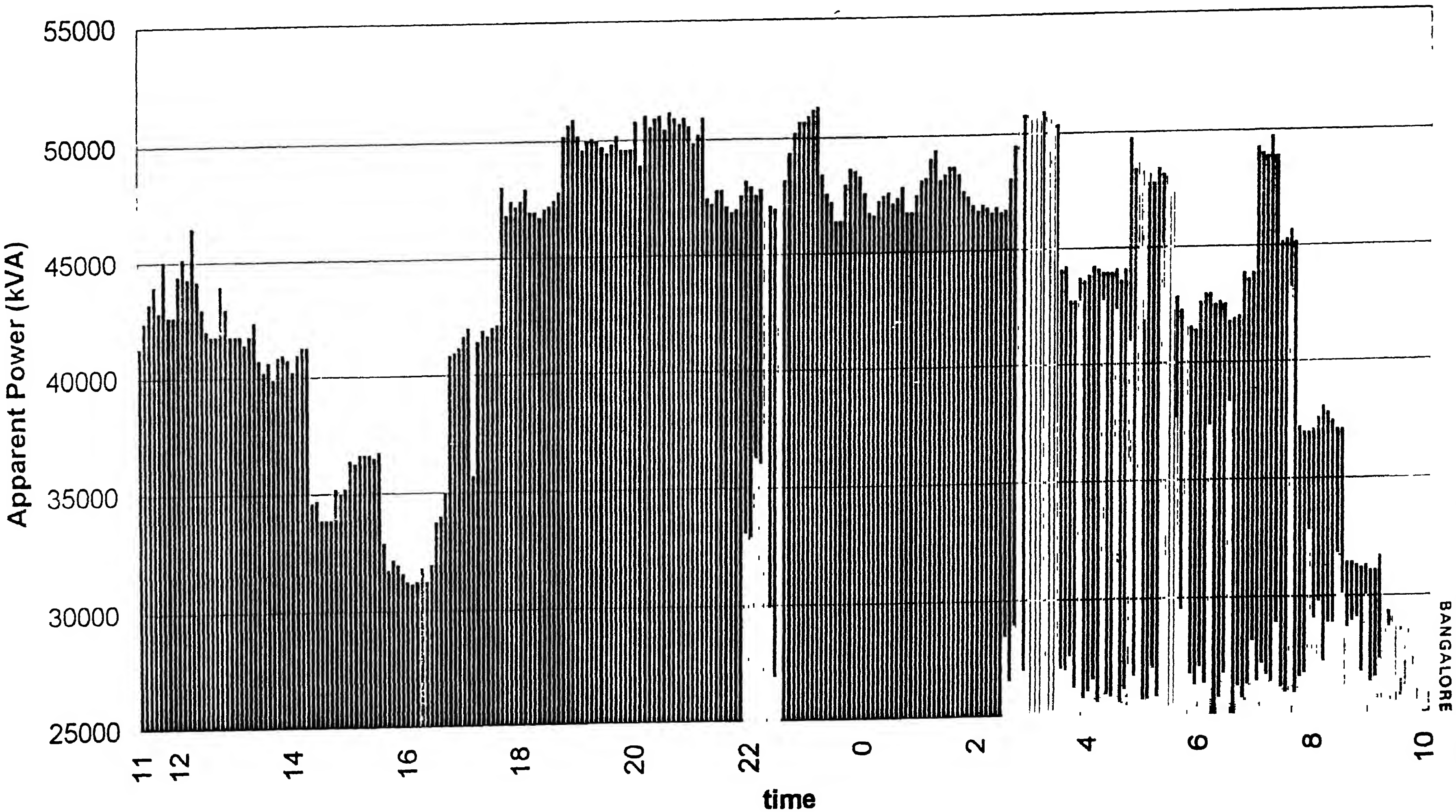
Variation in kVA Demand



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APPENDIX - 3/6

SYSTEM PARAMETERS
DETAILS OF CALCULATIONS AND RESULTS OF COMPUTER RUN

1. Load factor $= \dfrac{\text{Average load}}{\text{Peak load}}$

2. Loss load factor $= \dfrac{\Sigma I^2 x}{I^2_{max} \times 8760}$

Where

$E I^2 x = I^2_1 + I^2_2 + \dots\dots\dots. I^2 8760$

I_x = Load current

I_{max} = Peak load current

3. Input

Annual energy consumption (Nov 95-96) = 337.7 million kWh
(66 kV plant consumption)

Overall plant peak load = 56 67 MVA

Average PF = 0.92

Load curves = Typical working day

4. Results of computer run = 89 06%
Annual load factor
(considering 21 days shutdown)

Annual loss load factor = 0 85

5. Cost of electricity purchased

Demand charges = Rs.150 per kVA per month

Energy charges (average) = Rs.3.00 per kWh

6.6 kV - BUS - VOLTAGE ADJUSTMENT AT S/S - 1 (TRANSFORMER - NO - 3 OF MSS)

Observations							Remarks on Variations from Normal Position					
Tap Position	kV	Amps	Cosϕ	kVA	kW	kVAr	% Volt	Amps	Cosϕ	kVA	kW	kVAr
-3	6.42	527	0 96	6298	6029	1824	-3% -198 V	+10	+0 01	+20	+49	-69
-2	6.48	504	0 97	6163	5971	1522	-2% -132 V	-13	+0.02	-115	-18	-371
-1	6.54	504	0 96	6278	5971	1768	-1% -66 V	-13	+0 01	-115	-18	-125
Norm Posn	6.6	517	0 95	6317	5990	1893	-	-	-	-	-	-
+1	6.66	514	0 95	6317	6009	1997	+1% +66 V	-3	-	+39	+19	+84
+2	6.72	510	0 95	6317	5990	1997	+2% +132 V	-7	-	+39	-	+84
+3	6.78	507	0.94	6317	5990	2016	+3% +198 V	-10	-0.01	+39	-	+123

Normal tap position was kept at tap no.9

APPENDIX - 3/8

OPTIMUM BUS VOLTAGE CO-ORDINATION
DETAILS OF CALCULATIONS

1. PPF = K x APF

   Where PPF = Peak load power factor

   APF = Average Power Factor

   K = Ratio of load factor of apparent power to the load factor of active power.

   C_{KVAR} $^1(EI/E2)^2$

   Where

   C_{KVAR} =Output of capacitors in kVAr

   E_1 = Applied voltage across the capacitor

   E_2 = Rated voltage of the capacitor

3. Distribution Losses

   $= 3 \times I^2P \times R \times LLF \times UF$ Watt hours

   Where IP = Peak load current in Amps

   R = Resistance in Ohms

   LLF = Loss Load Factor

   UF = Utilisation factor

4 Input: Load curves, demand profile, voltage profile, PF profile 5 minute data for a typical production day -13th &14th December 1996

PROPOSAL

To operate the OLTCs of 15/20 and 20/25 MVA power transformers so as to maintain a voltage of 6.5 kV on the 6.6 kV bus

Appendix - 3/8 contd..

Reduction in Maximum demand	
Lowest bus voltage on 66 kV	= 60 kV
Total rated output of HT capacitor	= 7.962 MVAr
Total output of LT capacitors	= 4 712 MVAr
Peak load power factor as measured	= 0.91
Total capacitor output under existing conditions	= 12 674 MVAr
Capacitor output under proposed conditions	= 12.33 MVAr
Reduction in energy losses in equipments	
Estimated savings in power losses in HT & LT equipments due to marginal reduction in voltage	= 18 kW
Monthly savings in kVA M.D	= 881 kVA
Annual savings in energy losses	= 18 x 24 x 344 x 0.85
	= 9,68,430 kWh
Expected reduction in reactive power drawn	= 950 kVAr
Capital expenditure avoided due to available reactive compensation	= Rs 5.70 Lakhs
Annual cost of savings in maximum demand @ 50% of demand realised	= Rs.440 x 150 x 12
	= Rs 7.92 Lakhs
Total annual cost of energy savings (In addition to Rs 5 70 Lakhs capital savings)	= Rs.29 7 Lakhs
Cost of implementation	= Nil

APPENDIX - 3/9

POWER FACTOR MANAGEMENT

DETAILS OF CALCULATIONS

1. Existing Operating Conditions

Peak load Power Factor	= 0.92 (on 13.12.96 - 18.47 hrs)
Maximum demand (Dec'95)	= 50.16 MVA @ 60.6 kV
Average Power Factor	= 0.9378
Additional reactive compensation required to improve the power factor (peak load) to 0 94	= 2 90 MVAr

2. Proposed Operating Conditions

After implementation of recommendation under Bus voltage co-ordination. (Appendix - 3/8).

Peak load power factor (expected)	= 0 93
Average power factor	= 0.95
Expected reduction in reactive power	= 950 kVAr (App.3/8)
Additional reactive compensation required to improve the peak load P F to 0 94	= 1.95 MVAr
Resulting average power factor	= 0 96 and above
MD reduction due to bus voltage co-ordination	= 440 kVA (App.3/8)

Appendix - 3/9 contd..

System MD reduction with PF improvement	= 690 kVA
Costs saved due to kVA MD reduction	= Rs.12.42 Lakhs
Cost of investment @ Rs.600/- kVAr	= Rs.11.70 Lakhs
Payback period	= Less than 1 year

APPENDIX - 3/10

ENERGY SAVINGS BY SHIFTING CAPACITOR BANKS TO LOAD END BUS

Sl No.	Feeder Details	Measured Load (kW)	Max. Demand	Present PF	% Redn. in current	Capacitor connected kVAr	Savings in Distr loss kWh	Improved P.F.
1.	R1J13	76 5	95 1	0 78	13 6	25	1330	0 903
2	H1P14	35 7	51 5	0 69	18 5	15	83 7	0.847
3	W1X08	87	103 5	0 82	-	20	956	0 906
4.	W1J03	45 6	64 2	0 61	24	25	686	0.8
5	U2J06	48	54	0 68	22	25	1401	0 873
6	W1V07	55 8	78	0 67	20	25	920	0 835
7	W1V43	73 8	90	0 8	11	20	741	0 9
8	W1K10	63 5	90 6	0 65	21	30	406	0 821
9	R2J13	82 5	106 8	0 73	14	25	4470	0.845
10.	W2J03	97.5	115 8	0.83	8 5	20	4759	0 906
11.	W2U04	46 2	64 2	0 70	19	20	660	0 862
12	W2V07	58 1	72	0 77	14	20	1068	0.9
13	K2S03	122 4	170 1	0 74	11	30	587	0 833
14	X2P07	67 2	88 8	0 75	16	25	1705	0 891
			Total			**325**	**20,526**	

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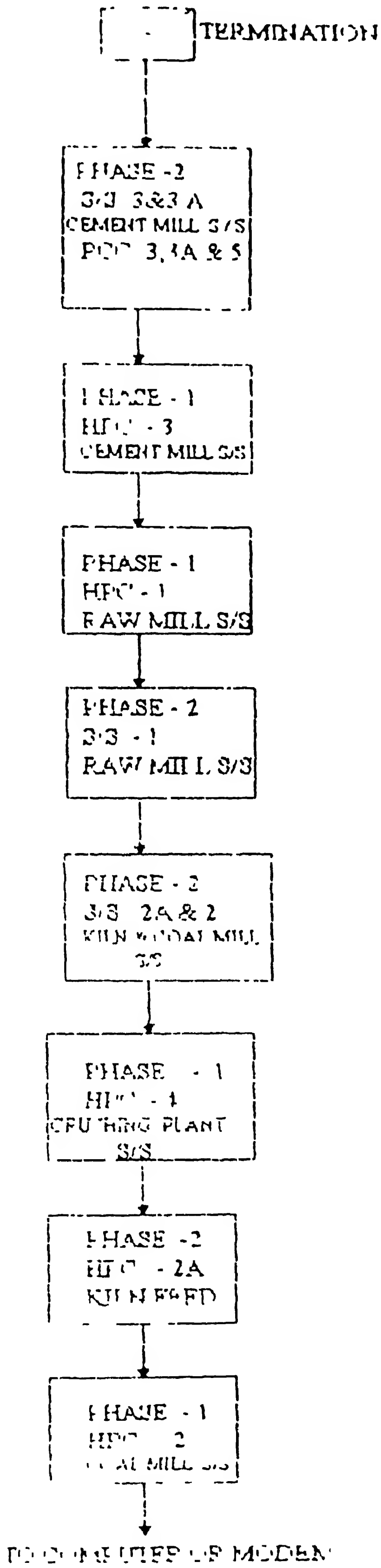
APPENDIX 3/11

BLOCK DIAGRAM OF METERING SYSTEM



APPENDIX - 3/12

SUPPLIERS LIST OF HARDWARE / SOFTWARE MANUFACTURERS

1 Sun Electronic Technology Ltd.
Rep. of Quad Logic System Inc.
177/2 C Bilekahalli
Bannerghatta Road
Bangalore -560 076

PH · (80) 665048

2. Power Measurement India Pvt. Ltd ,
12-G, Gopala Tower, 25, Rajedra Place,
New Delhi - 110 008

PH 5724196
FAX · 91-11-5766441/6881738

3 Energy Systems Pvt Ltd ,
47 & 47/1, II Floor, 6th Cross,
(Opp KSS Education Board)
Malleswaram,
Bangalore - 560 003

PH (80) 3312569
FAX (80) 3362085, 8460667

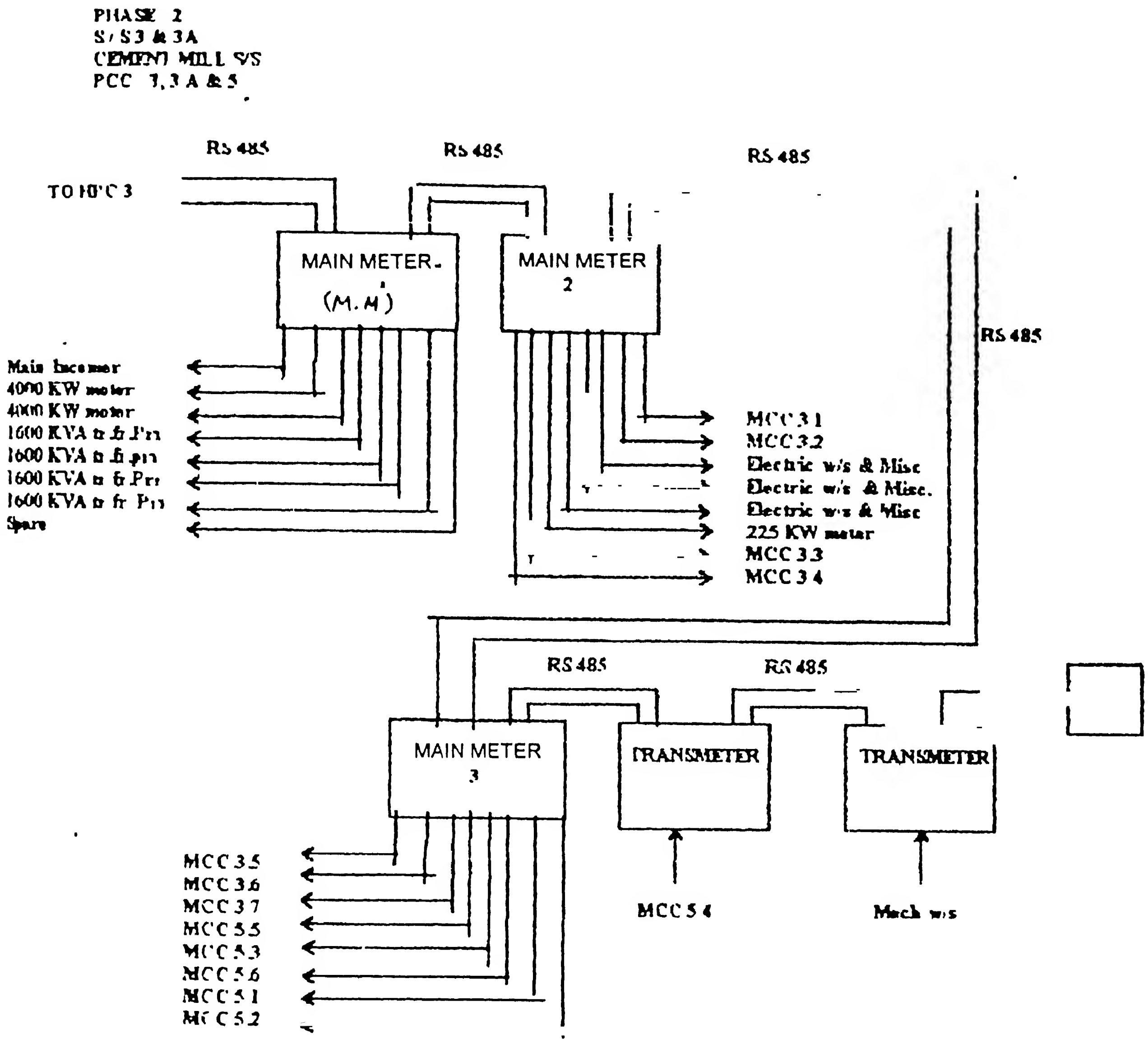
4 Alacrity Electronics Ltd ,
85, 6th Main Road,
Malleswaram,
Bangalore - 560 003

PH (80) 3345523
FAX (80) 3344593

APPENDIX 3/13

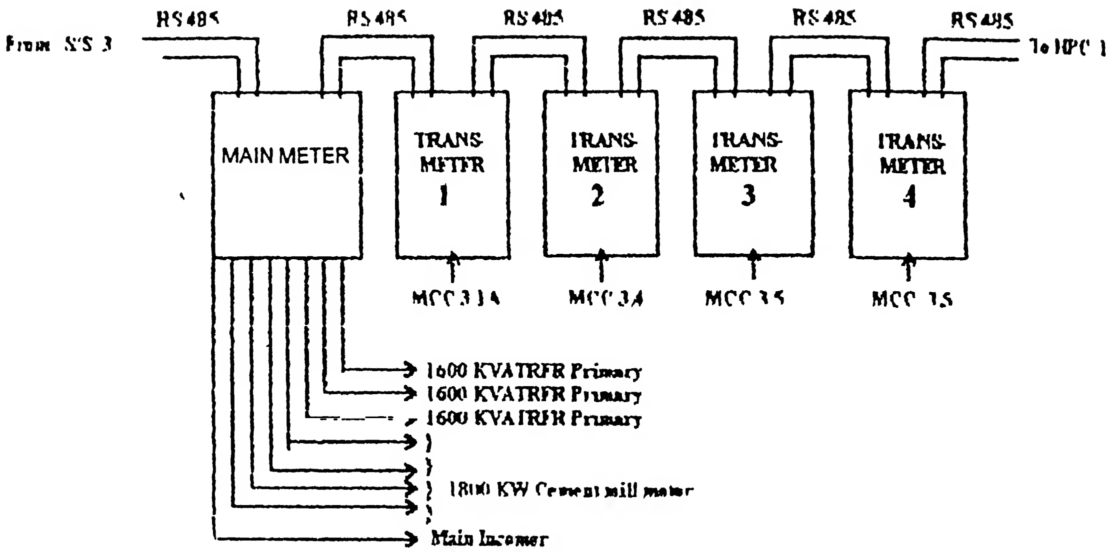
CONFIGURATION OF SUB-STATIONWISE METERING SYSTEM

1 -



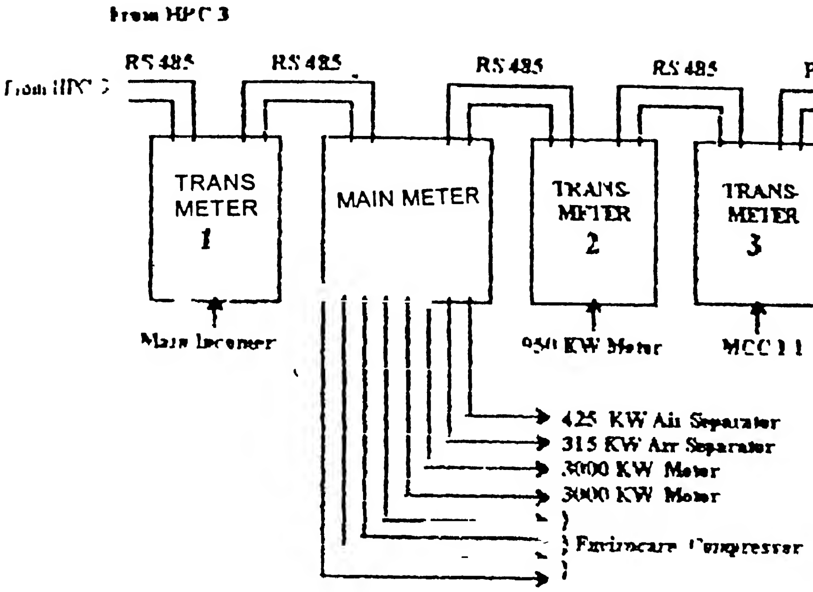
Appendix - 3/13 contd..

PHASE 1 :
HPC 3 :
Cement mill S/S

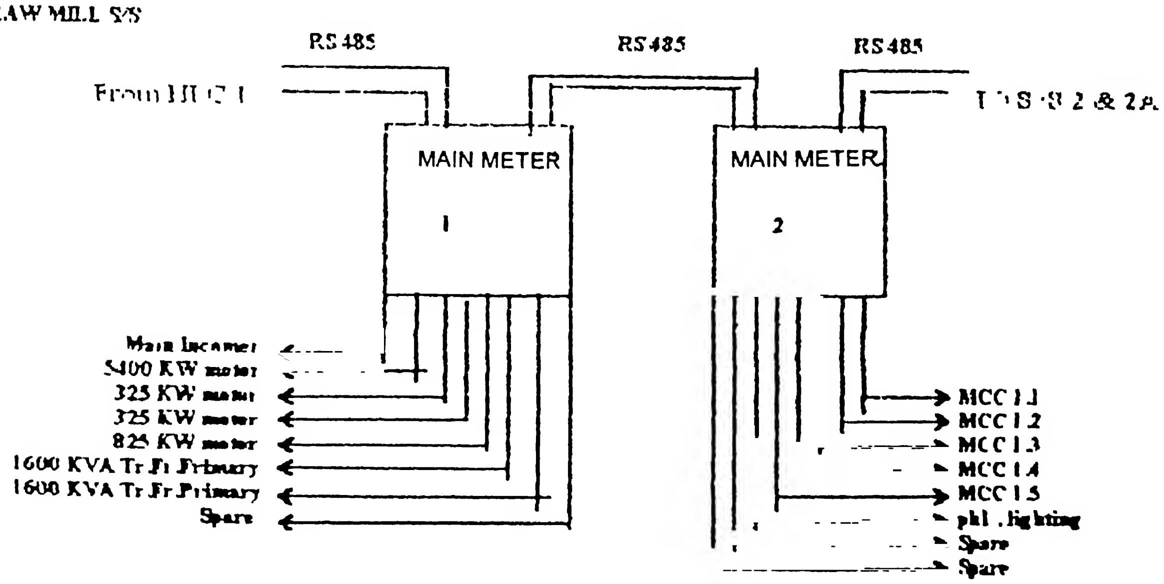


Appendix - 3/13 contd..

PHASE - I :
HPC 1 :
Raw mill S/S

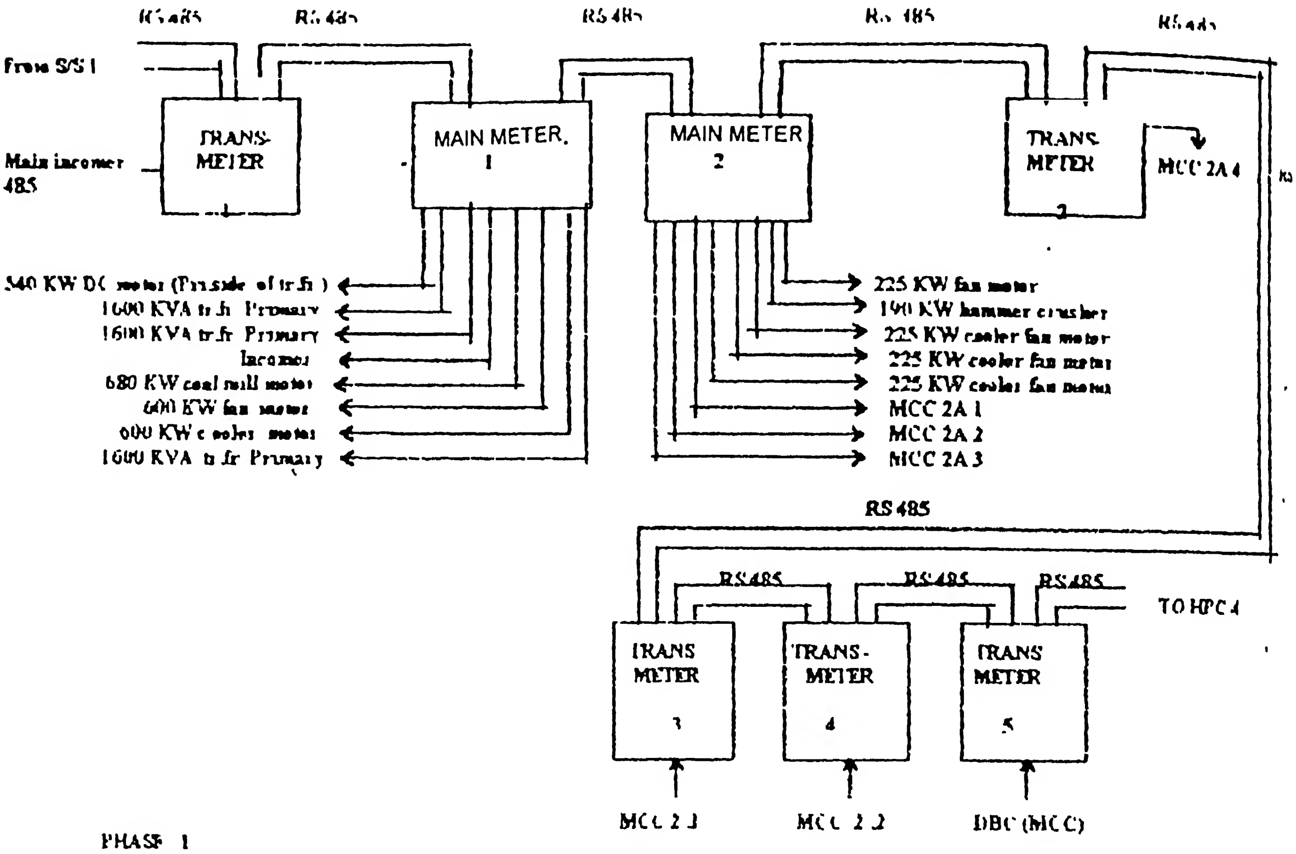


PHASE II
S/S 1
RAW MILL S/S

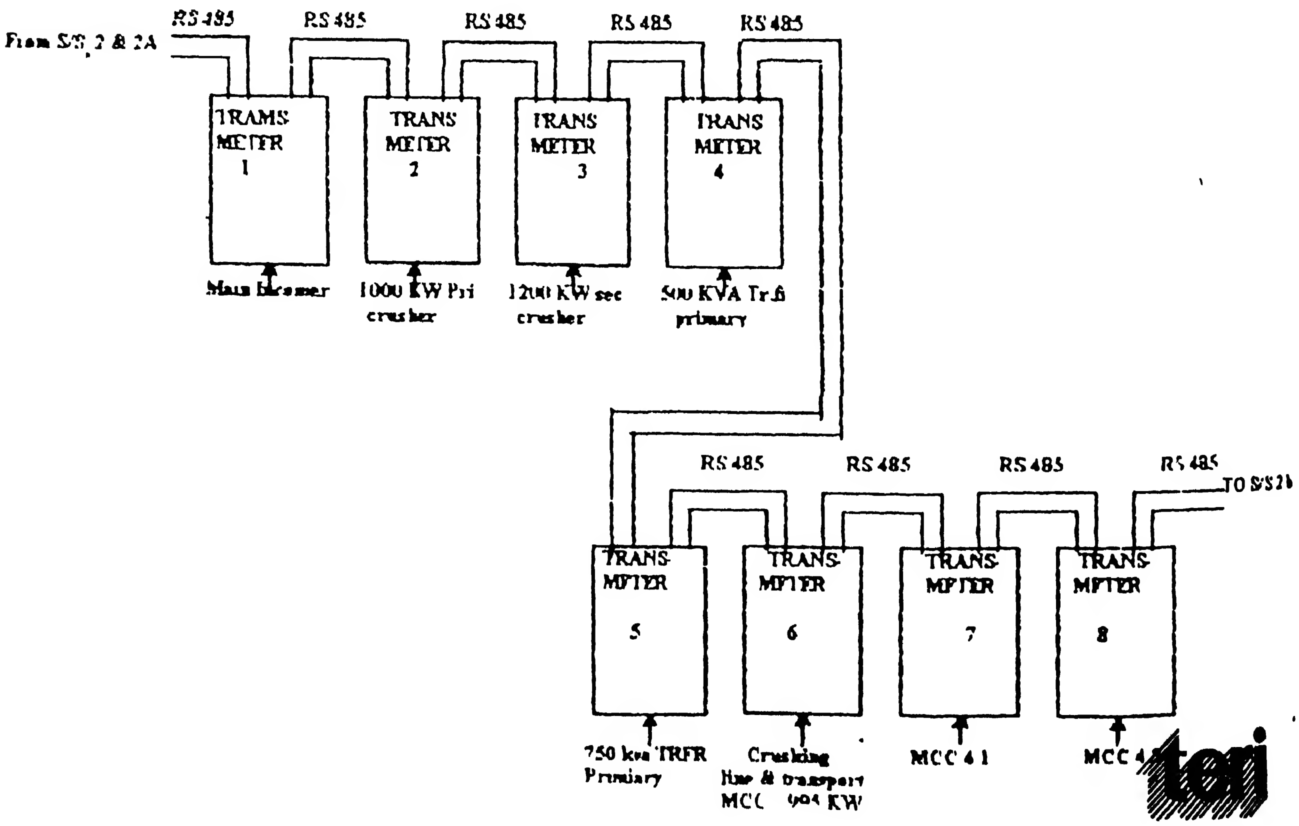


Appendix - 3/13 contd..

PHASE II
S/S 2A & 2
KILN & COAL MILL S/S

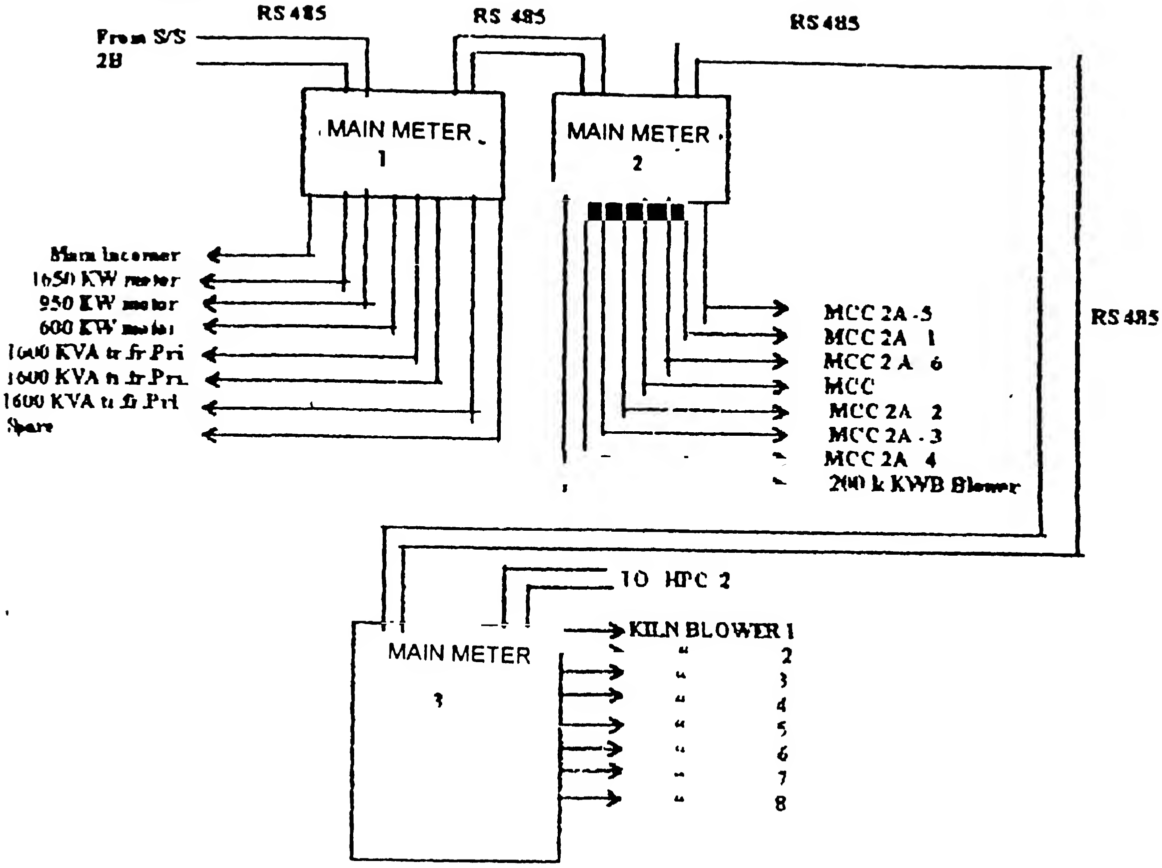


PHASE I
HPC 4
Crushing plant s/s

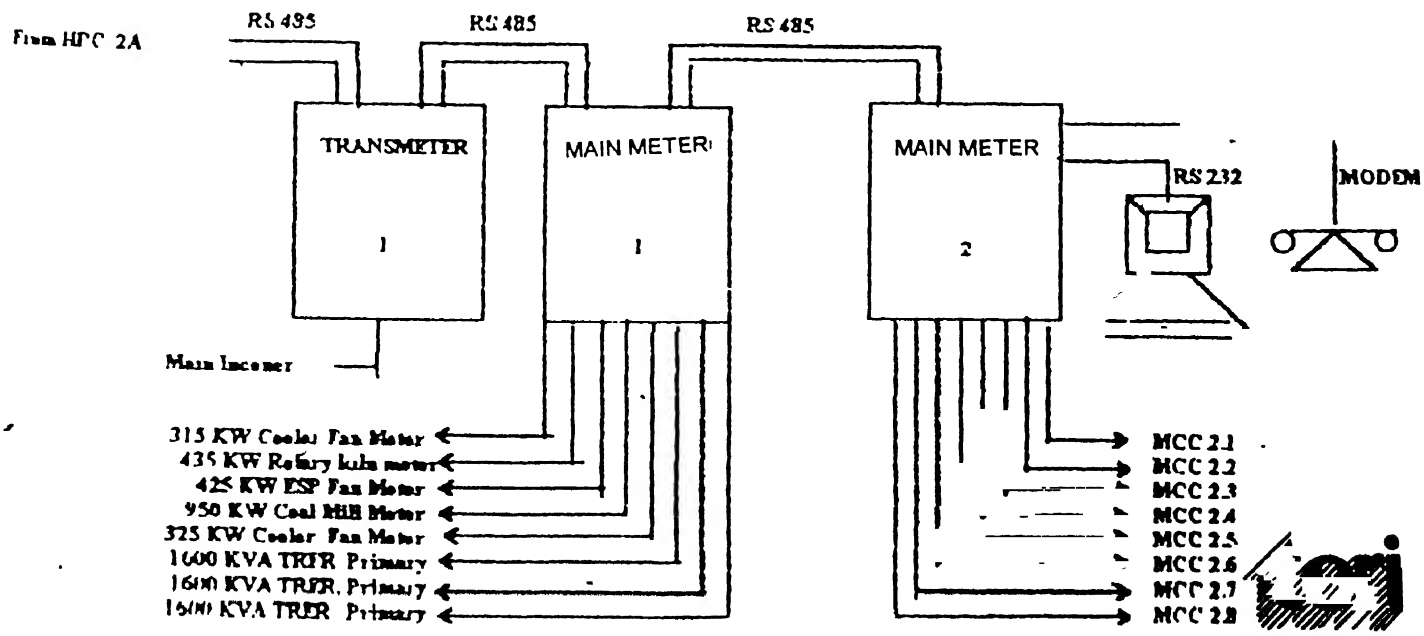


Appendix - 3/13 contd..

PHASE 2
HPC 2A
KILN FEED



PHASE 1 :
HPC - 2
Coal mill S/S



DESIGN PARAMETERS OF FANS

PHASE - I PROCESS FANS

Fan	Equipment Code	Quantity (m^3/min)	Total static pressure (mm Wg)	Temperature (^oC)	Motor rating (kW)
Calciner String smoke gas fan	J1JO1	6500	800	370	1800
Kiln String smoke gas fan	J1JO3	4100	800	350	950
Kiln ESP Fan	J1P44	12600	95	120	600
Raw Mill Fan	R1PO5	3900	610	90	700
Cooler ESP Fan	W1P51	9700	175	270	425
Coal mill vent fan	K1P56	860	620	60	160
Primary Air Fan	W1VO7	400	720	60	110
Cooler Fan - 1	W1K10	595	1000	50	225
Cooler Fan - 2	W1K11	950	1000	50	225
Cooler Fan - 3	W1K12	730	900	50	225
Cooler Fan - 4	W1K13	820	850	50	225
Cooler Fan - 5	W1K14	855	770	50	225
Cooler Fan - 6	W1K15	1020	650	50	225
Cooler Fan - 7	W1K16	2530	480	50	315
Cooler Fan - 8	W1K17	2530	405	50	325

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PHASE - II PROCESS FANS

Fan	Equipment Code	Quantity (m^3/min)	Total static pressure (mm Wg)	Temperature (^oC)	Motor rating (kW)
Calciner String smoke gas fan	J2JO1	6950	815	330	1650
Kiln String smoke gas fan	J2JO3	4100	620	330	825
Kiln ESP Fan	J2P09	12300	140	215	500
Raw Mill Fan	R2PO5	4200	675	90	825
Cooler ESP Fan	W2P31	10700	180	280	600
Coal mill vent fan	K2T01	2875	1256	74	600
Primary Air Fan	W2VO7	149	1300	25	90
Cooler Fan - 1	W2K10	620	750	30	132
Cooler Fan - 2	W2K11	870	700	25	225
Cooler Fan - 3	W2K12	940	650	25	225
Cooler Fan - 4	W2K13	845	560	25	225
Cooler Fan - 5	W2K14	845	560	25	132
Cooler Fan - 6	W2K15	830	480	25	132
Cooler Fan - 7	W2K16	2710	350	25	225
Cooler Fan - 8	W2K17	1660	250	25	132

Appendix - 4/1 contd..

PACKING PLANT

Capacity = 232 m^3/min
Total static pressure = 270 mm Wg
Temperature = 100 ^{O}C
Motor rating = 22 kW

Twin Lobe Compressors (Roots Blowers)

Equipment Code	Quantity (m^3/h)	Delivery Pressure (mm Wg)	Motor Rating (kW)
W1U43	4650	6500	160
W1U45	4315	9000	150

APPENDIX - 4/2

METHODOLOGY ADOPTED FOR MEASUREMENT OF PARAMETERS IN FAN

In case of forced draft fans like cooler fans, primary air fan where the inlet or suction side is not ducted and roots blowers, the quantity can be determined by the formula

Q	=	A x V
Where Q	=	Flow in m^3/s
A	=	Inlet area in m^2
V	=	Air velocity in m/s

The velocity of air at inlet point can be measured using Anemometer and by measuring the inlet area, the quantity can be found out

For induced draft fans or for fans where the inlet is ducted, the methodology adopted for measuring parameters are :

1 Static pressure, Dynamic pressure (Velocity pressure) and temperature are measured at the sample points for each fan

2 The density of air or gas at fan inlet (sample point) can be known from N T P values (1 4 kg/Nm^3 or 1 29 kg/Nm^3) by temperature and pressure correction

Density of preheater gas	=	1.4 kg/Nm^3
Density of air	=	1.29 kg/Nm^3

Density of air or gas at that particular point can be known by the formula :

$$\rho_2 = \rho_1 \frac{T_1}{T_2} \times \frac{P_2}{P_1}$$

ρ = Density, kg/m^3
P = Pressure, mm Wg
T = Temperature, K

Suffix -1 = Represents parameters at NTP

ρ_1 = 1.4 kg/Nm^3

P_1 = 1 bar = 10330 mm Wg

T_1 = 0 °C = 273 K

Suffix - 2 = Represents measured parameters at sample point

3. From Dynamic pressure & density at sample point velocity can be obtained from the formula

$$V = C \times \sqrt{\frac{2 \times g \times h}{\rho}}$$

Where, C = Pitot factor (0 86)
g = ACC due to gravity m/s^2
h = Dynamic pressure, mm Wg
ρ = Density at sample point (kg/m^3)

4. By knowing the area of sample point (Duct diameter), the quantity of flow (Q in m^3/s) can be known by :

Q = A x V
A = Area (m^2)
V = Velocity (m/s)

Appendix - 4/2 contd..

5. Theoretical power can be calculated from the formula,

$$kW = \frac{Q \times TP \times g}{3600 \times 1000}$$

Q = Flow in m^3/h
TP = Total static pressure (mm Wg)
g = Acceleration due to gravity (m/s^2)

Q & TP are measured parameters

6 Actual or measured power = $\frac{\text{Theoretical Power}}{\eta_{fan} \times \eta_{motor}}$

η = Efficiency

7 Fan efficiency is the ratio of Air Horse Power (theoretical power) to shaft power

APPENDIX - 4/3

MEASURED PARAMETERS FOR PROCESS FANS & CEMENT MILL ESP FANS

PHASE - I

Kiln Feed = 275 TPH
Raw mill feed = 310 TPH

Measured Parameters	Units	Smoke Gas Fans (J1J01)	Smoke Gas Fans (J1J03)	Kiln ESP Fan (J1P44)	Kiln ESP Fan (J1P44)	Raw Mill Fan (R1P05)	Cooler ESP Fan (W1P51)	Coal Mill Vent Fan (K1P56)	Cement Mill - I ESP Fan (Z1P05)	Cement Mill - II ESP Fan (Z2P07)
		Calciner String	Kiln String	Raw Mill in operation	Raw Mill not in operation					
Density	kg/m^3	0 591	0 577	0 9522	0 9133	1 064	0 6025	0 9655	0 892	0 894
Temperature	°C	304	318	114	130	57	290	57	106	101
Static Pressure	mmWg									
Suction side		- 852	- 852	- 104	- 116	- 576	- 114	- 718	- 144	- 256
Delivery side		+ 10	+ 10	+ 40	+ 40	+ 116	+ 20	+ 20	+ 10	+ 40
Dynamic (Velocity) Pressure, rms value	mm Wg	25 01	26 11	34 786	27 52	10 09	8 27	24 95	15 76	26.58
Duct Diameter	m	2 4	1 9	3.55	3.55	2 12	3 2	1 03	0 8	0 8
Velocity	m/s	24 78	25 63	23.02	20 91	11 73	14 11	19 366	16 01	20 77
Quantity	m^3/h	4,03,566	2,61,560	8,20,413	7,45,100	1,49,082	4,08,526	58,090	28,975	37,586
	Nm^3/h	1,70,363	1,07,800	5,57,998	4,86,071	1,13,302	1,90,808	43,479	20,035	26,048
Speed	%	96	96	90	86	100	62	100	100	100
Damper opening	%	100	100	100	100	40	45	100	100	100
Theoretical power	kW	948	614	322	317	281	149	117	12 16	30.32
Measured power	kW	1483	949	511		411	287	166 2	16.44	67.20

MEASURED PARAMETERS FOR COOLER FANS AND PRIMARY AIR FAN

PHASE - I

Density = 1.15135 kg/m^3
Temperature = 25 °C

Fans	Equipment Code	Quantity (m^3/h)	Delivery Pressure (mm Wg)	Total static pressure (mm Wg)	Damper Opening %	Speed %	Theoretical power (kW)	Measured Power (kW)
Cooler Fan - I	W1K10	16,350	442	1078	25	100	48 0	64 5
Cooler Fan - II	W1K11	22,161	416	666	30	80	40 2	54 9
Cooler Fan - III	W1K12	19,866	446	672	31	79	36 4	48.0
Cooler Fan - IV	W1K13	20,560	442	688	32	77	38 5	49.8
Cooler Fan - V	W1K14	28,002	414	738	25	100	56.3	74.4
Cooler Fan - VI	W1K15	24,395	390	772	31	100	51 3	68.7
Cooler Fan - VII	W1K16	1,22,109	274	470	70	100	156.4	214.0
Cooler Fan - VIII	W1K17	1,01,791	312	364	65	100	101.0	135.0
Primary Air Fan	W1V07	15,192	630	802	56	100	33.2	55.8

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Appendix - 4/3 contd.

MEASURED PARAMETERS FOR PACKING HOUSE DEDUSTING FANS

PHASE - I

Measured Parameters	Units	Silo - Top Fan (P1[illegible]72)	Silo - III Top Fan (P1P82)	Packer - I Fan (P1P12)	Packer - II Fan (P1P22)	Packer - III Fan (P1P32)	Packer - IV Fan (P1P42)
Density	kg/m^3	1 05	1.048	1.073	1 079	1.074	1 076
Temperature	°C	50	50	40	40	40	40
Static Pressure	mm Wg						
Suction side		- 112	- 142	- 199	- 162	- 195	- 187
Delivery side		+10	+ 10	+ 10	+ 10	+ 10	+ 10
Dynamic (Velocity) Pressure, rms value	mm Wg	13 2	8	48	38	40 4	42.71
Duct Diameter	m	0 45	0 45	0.45	0 45	0 45	0.45
Velocity	m/s	13 51	10.5	25.20	22 42	23 29	23.95
Quantity	m^3/h	7733	6020	14428	[redacted]2837	13333	13715
	Nm^3/h	6294	4900	12000	10737	11100	11440
Speed	%	100	100	100	100	100	100
Damper opening	%	100	100	80	50	80	80
Theoretical power	kW	2 57	2 33	8.22	6.02	7 45	7.36
Measured power	kW	4 0	4 4	10.62	9.44	12.4	12.3

APPENDIX - 4/4

MEASURED PARAMETERS FOR PROCESS FANS

PHASE - II

Kiln Feed = 360 TPH
Raw mill feed = 330 TPH

Measured Parameters	Units	Smoke Gas Fans (J2J01) (J2J03) Calciner String	Smoke Gas Fans Kiln String	Kiln ESP Fan (J2P09) Raw Mill in operation	Kiln ESP Fan (J2P09) Raw Mill Not in Operation	Raw Mill Fan (R2P05)	Cooler ESP Fan (W2P31)	Coal Mill Vent Fan (K2T01)	Coal Mill Hot Gas Fan (K2S03)
Density	kg/m^3	0 5995	0 635	0 9404	0 9288	0 9893	0 6076	0 9695	0 4846
Temperature	°C	295	270	118	122	84	286	52	426
Static Pressure	mm Wg								
Suction side		- 860	- 740	- 126	- 148	- 518	- 102	- 1342	- 128
Delivery side		+ 10	+ 10	+ 40	+ 40	+ 40	+ 20	+ 20	+ 116
Dynamic (Velocity) Pressure, rms value	mm Wg	18 67	13 97	31 73	24 48	16 41	3 81	37 91	9 173
Duct Diameter	m	2 65	2 12	2 8 x 2 8 Sq	2 8 x 2 8 Sq	2 24	3 15	1 27	1.5
Velocity	m/s	21 25	17 87	22 13	19 56	15 51	9 53	23 82	16 57
Quantity	m^3/h	4,22,045	2,27,073	6,24,515	5,51,988	2,20,103	2,67,366	1,08,632	1,05,414
	Nm^3/h	1,80,726	1,02,994	4,19,496	3,66,205	1,55,534	1,25,931	81,642	39,599
		95	99	93	93 5	85	62	100	100
Speed	%	100	100	100	100	100	63	56	35 - 45
Damper opening	%	1000	464	283	283	335	89	403	70
Theoretical power	kW	1530	707	420	407	540	210	595	122.4
Measured power	kW								

Appendix - 4/4 contd..

MEASURED PARAMETERS FOR COOLER FANS AND PRIMARY AIR FAN

PHASE - II

Density = 1.15135 kg/m^3
Temperature = 25 °C

Fans	Equipment Code	Quantity (m^3/h)	Delivery Pressure (mm Wg)	Total static pressure (mm Wg)	Damper Opening (%)	Speed (%)	Theoretical power (kW)	Measured Power (kW)
Cooler Fan - I	W2K10	11098	610	850	25	100	25.7	38.0
Cooler Fan - II	W2K11	32486	636	732	28	100	64.8	96.0
Cooler Fan - III	W2K12	31983	582	708	26	100	61 7	87.9
Cooler Fan - IV	W2K13	29814	580	670	33	100	54 4	75.6
Cooler Fan - V	W2K14	33491	552	588	70	100	53.6	79.5
Cooler Fan - VI	W2K15	67580	388	438	40	100	80.6	114.9
Cooler Fan - VII	W2K16	96037	354	408	88	100	106.7	152.1
Cooler Fan - VIII	W2K17	61560	190	338	100	100	56.7	84.0
Primary Air Fan	W2V07	6220	1100	1314	65	100	22.3	58.0

MEASURED PARAMETERS FOR CEMENT MILL ESP FANS & PACKING HOUSE DEDUSTING FANS

PHASE - II

Measured Parameters	Units	Cement Mill - III ESP Fan (Z3P05)	Cement Mill - IV ESP Fan (Z4P05)	Silo - V Top Fan (P2P67)	Silo - VI Top Fan (P2P69)	Packer - V Fan (P2P12)	Packer -VI Fan (P2P22)	Packer -VII Fan (P2P32)	Packer - IX Fan (P2P52)
Density	kg/m^3	0 895	0 8896	1 016	0 98	1 070	1 067	1 072	1 073
Temperature	°C	104	106	55	71	41	41	41	41
Static Pressure	mmWg								
Suction side		- 170	- 174	- 290	- 202	- 212	- 241	- 195	- 199
Delivery side		+ 10	+ 10	+ 10	+ 10	+ 4	+ 4	+10	+ 6
Dynamic (Velocity) Pressure, rms value	mm Wg	20 14	18 58	9	10 6	40 4	29 6	36	36
Duct Diameter	m	0 8	0 8	0.46	0 46	0 49	0 49	0 49	0.49
Velocity	m/s	18 07	17 41	11 34	12 53	23 12	19 78	21 82	21 82
Quantity	m^3/h	32,699	31,502	6,783	7,495	15,693	13,428	14,814	14,814
	Nm^3/h	22,687	21,724	5,342	5,694	13,017	11,107	12,305	12,305
Speed	%	100	100	100	100	100	100	100	100
Damper opening	%	100	100	100	100	100	100	100	100
Theoretical power	kW	16 04	15 80	5 55	4.33	7 87	9 18	8.28	8 28
Measured power	kW	35.10	22 50	10 9	14.9	15 8	15.3	13.8	15.6

APPENDIX - 4/5

ARRESTING FALSE AIR IN KILN ESP AND RAW MILL CIRCUIT PHASE - I

KILN ESP CIRCUIT

1. The total flow of smoke gas fans = 1,70,363 + 1,07,800

   = 2,78,163 Nm^3/h .... (A)

   (Nm^3/h is based on 0 °C and 1 bar)

2. Flow of kiln ESP Fan when Raw mill is not in operation = 4,86,071 Nm^3/h .... (B)

3. Flow of kiln ESP Fan when Raw mill is in operation = 5,57,998 Nm^3/h .... (C)

4. Total excess air handled by kiln ESP fan = C - A

   = 2,79,835 Nm^3/h

   $$= \frac{2,79,835 \times 1.4}{0.9522}$$

   (Density of gas at N T P. = 1.4 kg/Nm^3)
   (Density of gas at sample point = 0.9522 kg/m^3)

   = 4,11,436 m^3/h

5. Corresponding power loss $$= \frac{Q \times TP \times g}{3600 \times 1000 \times \eta_{fan} \times \eta_{motor}}$$

Where Q = Flow in m^3/h (4,11,436)
TP = Total static pressure in mm Wg (144)
g = Acceleration due to gravity in m/s^2 (9.81)

Appendix - 4/5 contd..

$$= \frac{411436 \times 144 \times 9.81}{3600 \times 1000 \times \eta_{fan} \times \eta_{motor}}$$

(Assuming efficiency of motor as 90%, the calculated efficiency of fan from the measured values comes to 70%).

= 256 kW / h

6 Assuming 80% of this leakage can be arrested, power savings will be	= 256 x 0.8
	= 205 kW /h
7. Annual energy loss (@ 24 hours/day & 330 days/yr)	= 205 x 24 x 330
	= 16,23,600 kWh/year

By arresting the false air entry into the circuit the annual cost savings that can be obtained by kiln ESP fan

= 1623600 x 3
(@ Rs.3.00/kWh)

= Rs.48,70,800

Annual cost savings	= Rs.48.70 lakhs
Investment required	= Marginal
Simple payback period	= Immediate

RAW MILL CIRCUIT

Excess air through Raw Mill Circuit	= C - B
	= 71927 Nm^3/h
Corresponding power loss	= 267 kW / h
Assuming 80% of this leakage can be arrested, power savings will be	= 267 x 0 8
	= 214 kW / h
Annual power loss (@ 24 hours /day and 330 days/yr)	= 214 x 24 x 330
	= 16,94,880 kWh

By arresting the false air entry into the Raw mill circuit,

Annual cost savings by Raw mill fan (@ Rs 3.00/kWh)	= 16,94,880 x 3
	= Rs 50,84,640
	= Rs 50 84 Lakhs
Investment	= Marginal
Simple payback period	= Immediate

APPENDIX - 4/6

ARRESTING FALSE AIR IN KILN ESP AND RAW MILL CIRCUIT PHASE - II

KILN ESP CIRCUIT

1	The total flow of smoke gas fans	= 1,80,726 + 1,02,994
		= 2,83,720 Nm^3/h ....A
		(Nm^3/h is based on 0 °C and 1 bar)
2.	Flow of kiln ESP Fan when Raw mill is not in operation	= 3,66,205 Nm^3/h .... B
3.	Flow of kiln ESP Fan when Raw mill is in operation	= 4,19,496 Nm^3/h ... C
4	Total excess air handled by kiln ESP fan	= C - A
		= 1,35,776 Nm^3/h
5	Corresponding power loss	= 135 kW / h
6	Assuming 80% of this leakage can be arrested, power savings will be	= 135 x 0 8
		= 108 kW / h
7	Annual power loss (@ 24 hrs/day + 330 days/annum)	= 108 x 24 x 330
		= 8,55,360 kWh/year

Appendix - 4/6 contd..

By arresting the false air entry into the circuit the annual cost savings that can be obtained by kiln ESP fan

= 8,55,360 x 3
(@ Rs.3 00/kWh)

= Rs.25,66,080

Annual cost savings	= Rs.25 66 Lakhs
Investment required	= Marginal
Simple payback period	= Immediate

Appendix - 4/6 contd..

RAW MILL CIRCUIT

Excess air through Raw Mill Circuit	= C - B
	= 53291 Nm^3/h
Corresponding power loss	= 183 kW / h
Assuming 80% of this leakage can be arrested, power savings will be	= 183 x 0.8
	= 146 kW / h
Annual power loss (@ 24 hours /day and 330 days/yr)	= 146 x 24 x 330
	= 11,56,320 kWh

By arresting the false air entry into the Raw mill circuit,

Annual cost savings by Raw mill fan (@ Rs.3/kWh)	= 11,56,320 x 3
	= Rs.34,68,960
Annual cost savings	= Rs.34 68 Lakhs
Investment	= Marginal
Simple payback period	= Immediate

APPENDIX - 4/7

REDUCE SPEED OF PHASE - II COAL MILL VENT FAN BY 20%

Present rpm of phase - II coal mill vent fan	= 992 rpm
Static pressure before damper	= - 822 mm Wg
Static pressure after damper	= - 1342 mm Wg
Pressure loss across damper	= 520 mm Wg

Measured parameters for this fan are

Q = 1,08,632 m^3/h, Temperature = 52 °C

So, power loss due to pressure loss across damper	= 204 kW
Assuming 90% of this loss can be recovered by reducing rpm	= 204 x 0 9
	= 184 kW
Annual energy loss (@ 18 hours/day, 330 days/year)	= 184 x 18 x 330
	= 10,92,960 kWh

In order to reduce the pressure loss across damper, it is recommended to reduce the present rpm of 992 to 794 i e, by 20% using gear box and operate the damper at more than 90% and thereby save energy to the extent of 10,92,960 kWh annually.

Annual cost savings	= 10,92,960 x 3
	= Rs 32,78,880
	= Rs 32.78 Lakhs
Investment required	= Rs 4 00 Lakhs
Simple payback period	= 2 Months

APPENDIX - 4/8

VARIABLE SPEED FLUID COUPLING FOR PHASE - II COAL MILL HOT GAS FAN

Static pressure at suction side = - 128 mm Wg

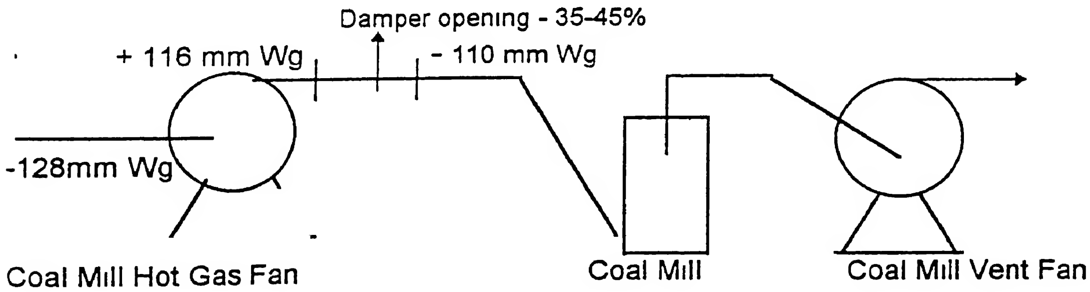
Damper is provided on the delivery side of the fan and its opening ranges from 35% to 45 %

Static pressure before damper = + 116 mm Wg

Static pressure after damper = - 110 mm Wg

The pressure before damper is delivery pressure while after damper it is suction pressure This infers the influence of coal mill vent fan after damper

By operating damper from 80% instead of present 35%, by varying the rpm of the fan using variable speed fluid coupling, the influence of coal mill vent fan can further be extended ie , almost till the delivery of the hot gas fan This reduces the total static pressure of the fan as the delivery of hot gas fan is suction pressure and hence result in lesser power consumption



Power loss = 44 kW

Appendix - 4/8 contd.

By using variable speed fluid coupling only 25% of this power loss can be saved, considering the losses in variable speed fluid coupling when operated at low speed.

Annual energy savings (@ 18 hours/day, 330 days)	= 11 x 18 x 330
	= 65,340 kWh
Annual cost savings	= Rs 1,96,020/-
	= Rs 1 96 Lakhs
Investment required	= Rs 4 00 Lakhs
Simple payback period	= 2 04 years

APPENDIX - 4/9

COMBINED OPERATION OF DAMPERS AND VARIABLE SPEED DRIVES FOR COOLER FANS

For Phase - I all cooler fans are provided with variable speed drives while for Phase - II cooler fans I - V are provided with variable speed drive but not yet commissioned

For fans starting from W1K12, the variable speed drives and dampers can be operated in combination so that pressure loss across damper and hence power consumption is reduced Considering process conditions, W1K10 and W1K11 are operated with damper

Fans	Quantity (m³/h)	Damper opening (%)	Pressure loss across damper (mm Wg)	Power Loss (kW / h)
PHASE - I				
W1K12	19,866	31	156	9
W1K13	20,560	32	178	10
W1K14	28,002	25	266	22
W1K15	24,395	31	312	24
W1K16	1,22,109	70	132	48
W1K17	1,01,791	65	30	9
TOTAL				122
PHASE - II				
W2K12	31,983	26	112	11
W2K13	29,814	33	80	7
TOTAL				18

Total power loss = 140 kW

Appendix - 4/9 contd.

By combined operation of variable speed drive and damper, assuming 80% of this loss can be eliminated,

Power savings	= 140 x 0 8
	= 112 kW
Annual energy savings	= 112 x 24 x 330
	= 8,87,040 kWh
Annual cost savings	= Rs 26,61,120
	= Rs.26.61 Lakhs
Investment required	= Nil
Simple payback period	= Immediate

APPENDIX - 4/10

REPLACEMENT OF COOLER ESP FANS WITH CORRECT SIZE AND HIGH EFFICIENCY FANS

The cooler ESP fan measured parameters are

Data	Phase - I	Phase - II
Flow quantity	4,08,526 m^3/h	2,67,366 m^3/h
Total static pressure	134 mm Wg	122 mm Wg
Static pressure before damper	- 18 mm Wg	- 18 mm Wg
Static pressure after damper	- 113 mm Wg	- 100 mm Wg
Temperature	290 °C	286 °C

PHASE - I

The fan is presently being operated at 62% speed and 45% damper opening In order to reduce the pressure loss across damper (95 mm Wg), it is generally recommended to reduce the speed and open damper further. But here further reduction in speed is not possible as the suction developed by the fan is presently less (18 mm Wg before damper) This low suction pressure may be due to the higher size of duct (3 2 m diameter)

The total static pressure of 134 mm Wg is mainly due to higher pressure loss across damper. For the above parameters, the theoretical power is 149 kW, while the measured power is 287 kW

Assuming motor efficiency as 90%, the fan efficiency comes to only 58%. This low efficiency is mainly due to operating fan at lower speed and with damper.

Appendix - 4/10 contd.

Using correct size and high efficiency fans, fan efficiency at the rate of 75% can be achieved with ease

So, power savings using high efficiency fans	= 66 kW
Annual energy savings (@ 24 hours/day and 330 days/year)	= 66 x 24 x 330
	= 5,22,720 kWh
Annual cost savings (@ Rs 3/kWh)	= 5,22,720 x 3
	= Rs 15,68,160/-
	= Rs 15.68 Lakhs
Investment required	= Rs.8.00 Lakhs
Simple payback period	= 7 Months

Appendix - 4/10 contd.

PHASE - II

For this fan it was observed that the suction pressure before damper is 18 mm Wg, while after damper is 100 mm Wg. This low suction pressure before damper may be due to higher size of duct (3 15 m diameter) So here also it is not possible to reduce the rpm further and thereby avoid pressure loss across damper This total static pressure of 100 mm Wg is mainly due to high pressure loss across damper.

For the above mentioned parameters the theoretical power is 89 kW while the measured power is 210 kW Assuming a motor efficiency of 90%, the fan efficiency comes to only 47% This low efficiency is mainly due to operating fan at lower speed and with damper.

When coal mill is not in operation, the measured parameters are

Flow quantity	= 3,61,503 m^3/h
Total static pressure	= 126 mm Wg
Temperature	= 247 °C

Here the theoretical power is 124 kW, while the measured power is 230 kW Assuming motor efficiency as 90%, the fan efficiency comes to only 60% Since higher capacity fan is used (10,700 m^3/min) here the more the quantity handled by the fan, the higher is the efficiency of fan.

By using correct size and high efficiency fans, fan efficiency of 75% can be achieved with ease.

So, power savings = 78 kW

Appendix - 4/10 contd..

Annual energy savings (@ 24 hours/day, 330 days/year)	= 78 x 24 x 330
	= 6,17,760 kWh
Annual cost savings (@ Rs 3/kWh)	= Rs 18,53,280
	= Rs 18 53 Lakhs
Investment	= Rs 8 00 Lakhs
Simple payback period	= 6 Months

APPENDIX - 4/11

OPERATION OF RAW MEAL SILO TOP BAG FILTER FANS

PHASE - I :

The power consumed by Phase- I silo top bag filter fan is 35 7 kW and Phase - II silo top bag filter is 28 2 kW / h

Since mechanical handling is in operation presently, these fans are not required to be operated as there are separate dedusting fans for mechanical handling equipments (Bucket elevators)

Assuming in a year, the bucket elevators are operated for 300 days, these two fans can be stopped for the same period

The power savings that can be achieved	= 35.7 + 28.2
	= 63.9 kW
Annual energy savings (@ 24 hours/day/300 days/year)	= 63.9 x 24 x 330
	= 5,06,088 kWh
Annual cost savings (@ Rs 3/kWh)	= 5,06,088 x 3
	= Rs.15,18,264
	= Rs.15 18 Lakhs
Investment required	= Nil
Simple payback period	= Immediate

REDUCE SPEED OF PHASE - I PRIMARY AIR FAN BY 10% AND REPLACE EXISTING DAMPER WITH INLET GUIDE VANE CONTROL

Measured parameters for the fan are

Quantity	= 15,192 m^3/h
Static pressure at suction side	
Before damper	= - 5 mm Wg
After damper	= -172 mm Wg
Pressure loss across damper	= 167 mm Wg
Static pressure at delivery side	= + 630 mm Wg
Total static pressure	= 630 - (-172)
	= 802 mm Wg
Required total static pressure by eliminating damper loss	= 802 - 167
	= 635 mm Wg

As per fan law, pressure is proportional to square of speed

i e.,

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^2$$

Appendix - 4/12 contd..

Present speed	= 100%
Present total static pressure	= 802 mm Wg

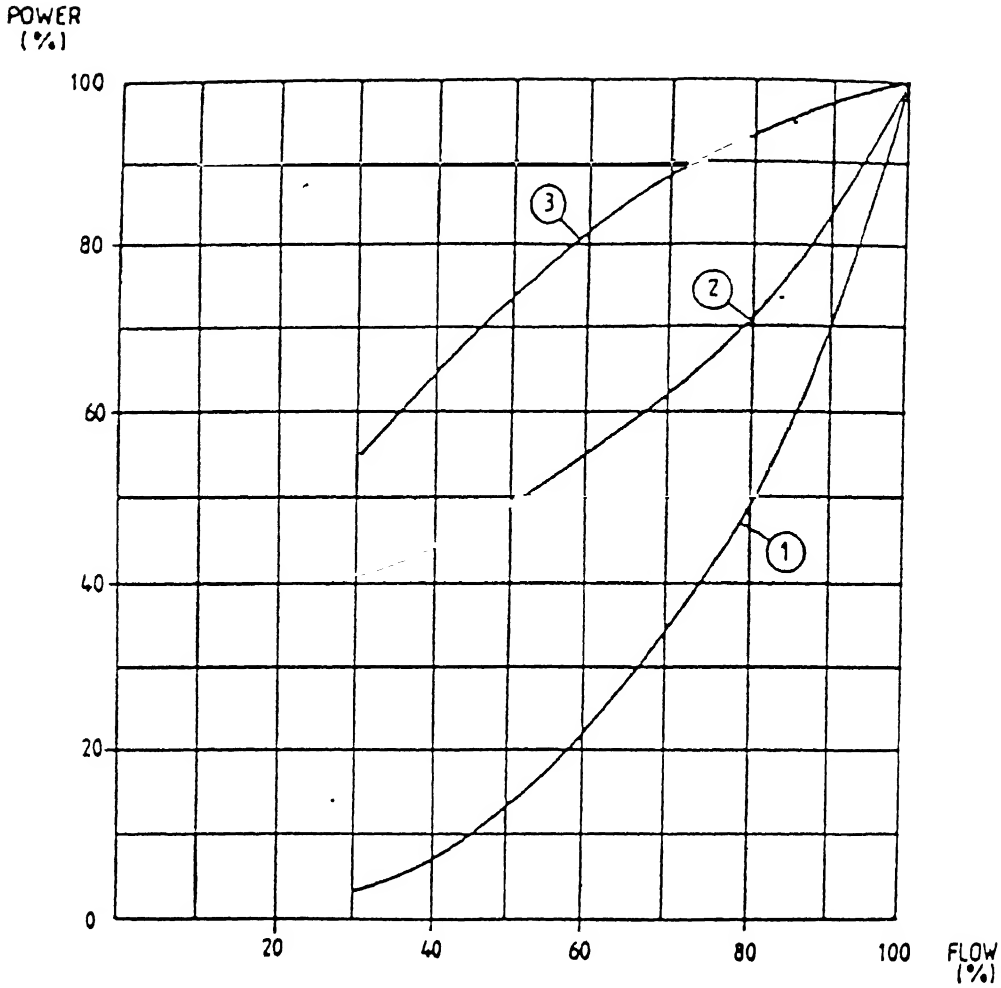
$$\therefore \frac{802}{635} = \left(\frac{100}{N_2}\right)^2$$

$$\therefore N_2 = 89$$

∴ Required speed	= 89%
∴ Reduce rpm of P A fan by 10%	
Power savings by reducing rpm and using inlet guide vane control	= 11 kW
Annual energy savings (@ 24 hrs/day, 330 days/year)	= 11 x 24 x 330
	= 87,120 kWh
Annual cost savings (@ Rs 3/kWh)	= 87,120 x 3
	= Rs.2,61,360
	= Rs.2.61 Lakhs
Investment required	= Rs.40,000/-
Simple payback period	= 2 Months

APPENDIX - 4/13

QUALITATIVE COMPARISON OF FAN CONTROL SYSTEMS



1. Speed control
2. Inlet guide vane control
3 Throttle damper

APPENDIX - 4/14

REPLACEMENT OF PHASE - II PRIMARY AIR FAN WITH HIGH EFFICIENCY FAN AND INLET GUIDE VANE CONTROL

	Measured Parameters	
	Quantity (m^3/h)	Total Static Pressure (mm Wg)
Phase - II	6220	1314

The theoretical power for above mentioned parameters is $= \dfrac{6220 \times 1314 \times 9\ 81}{3600 \times 1000}$

= 22 3 kW

Measured power = 58 kW

Assuming motor η as 80%, the fan efficiency comes to 48%

Replacing this fan with high efficiency fan (η = 75%) and inlet guide vane control, the estimated power savings is 20 8 kW as the new fan is expected to consume only 37 2 kW.

Annual energy savings (@ 24 hours/day, 330 days/year) = 20 8 x 24 x 330

= 1,64,736 kWh

Annual cost savings (@ Rs.3 /kWh) = Rs.1,64,736 x 3

= Rs.4,94,208 Lakhs

= Rs 4.94 Lakhs

Investment required = Rs 3 00 Lakhs

Simple payback period = 8 Months

APPENDIX - 4/15

OPERATE CEMENT MILL - II ESP FAN (Z2P07) SIMILAR TO OTHER CEMENT MILLS ESP FAN

Cement Mill No.	Quantity (m^3/h)	Total static pressure (mm Wg)	Power Consumption (kW)
ESP Fan - 1	28,975	154	16 4
ESP Fan - 2	37,586	296	67 2
ESP Fan - 3	32,699	180	35 1
ESP Fan - 4	31,502	184	22 5

The above measured parameters clearly indicate the high static pressure developed by cement mill - II ESP fan (Z2P07) By operating the fan similar to other fans, i e, near ESP itself the total static pressure will come down resulting in less power consumption

Expected power consumption for same flow and 190 mm Wg total static pressure = 40 kW

Also by going in for correct size and high efficiency (η = 75%) fan, the expected power consumption is 30 5 kW

So, by operating correct size and high efficient fan at the place similar to other cement mill ESP fans, the expected power consumption is 30 5 kW

Hence power savings = 67 2 - 30 5

= 36 7 kW

Annual energy savings (@ 24 hours/day, 330 days/year) = 36 7 x 24 x 330

= 2,90,664 kWh

Appendix - 4/15 contd

Annual cost savings (@ Rs 3/kWh)	= 2,90,664 x 3
	= Rs.8,71,992
	= Rs 8 71 Lakhs
Investment required	= Rs.2 00 Lakhs
Simple payback period	= 3 Months

REPLACE CEMENT MILL - III ESP FAN (Z3P05) WITH HIGH EFFICIENCY FAN

The measured parameters for this fan are

Quantity	= 32,699 m^3/h
Total static pressure	= 180 mm Wg
Temperature	= 104 °C

The theoretical power required for this parameter is 16 kW Assuming motor efficiency as 90%, the fan efficiency comes to 51% as the measured power is 35 1 kW

By replacing the fan with high efficiency fan (η= 75%),

The power savings	= 11 kW
Annual energy savings (24 hours/day, 330 days/year)	= 11 x 24 x 330
	= 87,120 kWh
Annual cost savings (@ Rs 3/kWh)	= Rs 2,61,360
	= Rs 2.61 Lakhs
Investment required	= Rs 2.00 Lakhs
Simple payback period	= 10 Months

APPENDIX - 4/17

REPLACE SILO- 6 TOP FAN (P2P69) IN PACKING HOUSE WITH HIGH EFFICIENCY FAN

The measured parameters for this fan are

Quantity	= 7495 m^3/h
Total static pressure	= 222 mm Wg
Temperature	= 71 °C

The theoretical power required for this parameter is 4 33 kW while the measured power is 14 9 kW So, fan efficiency = 41% (Assuming motor efficiency as 70%)

By replacing this fan with high efficiency fan (η= 75%),

The power savings	= 9 kW
Annual energy savings (24 hours/day, 330 days/year)	= 9 x 24 x 330
	= 71,280 kWh
Annual cost savings (@ Rs 3/kWh)	= Rs.71,280 X 3
	= Rs 2,13,840 Lakhs
	= Rs 2 13 Lakhs
Investment required	= Rs.2.00 Lakhs
Simple payback period	= 12 Months

OPTIMISE AIR QUANTITY USED FOR CONVEYING COAL TO KILN AND CALCINER

The pulverised coal is conveyed to kiln and calciner by roots blower air through F K. Pump/C P Pump

	Equipment	Measured quantity of air	Quantity of Material Conveyed per Ton of air	
			Actual	Norm
Phase - I	Kiln firing roots blower (W1U45)	2520 m^3/h = 2 90 T	13 / 2.9 = 4 48 T	14 T
	Calciner firing roots blower (W1U43)	3268 m^3/h = 3.76 T	22 / 3 76 = 5 85 T	
Phase - II	Kiln firing roots blower (W2U04)	2053 m^3/h = 2 36 T	13 / 2 36 = 5 51 T	
	Calciner firing roots blower (W2U09)	4345 m^3/h = 4 73 T	22 / 4 73 = 4 65 T	

REDUCE RPM OF ALL BLOWERS BY 40% IN STAGES OF 10%

ENSURE PRESENT VELOCITY IS MAINTAINED BY CHANGING PIPE SIZE

Total power savings	= 100 kW
Annual energy savings (@ 24 hours/day, 330 days/year)	= 100 x 24 x 330
	= 7,92,000 kWh
Annual cost savings (@ Rs 3.00/kWh)	= 7,92,000 x 3
	= Rs 23,76,000
	= Rs 23 76 Lakhs
Investment required	= Rs 4 00 Lakhs
Simple payback period	= 2 Months

COMPRESSOR SPECIFICATIONS

Sl No	ID Code	Type*	No of stages	Design pressure, $kg/cm^2(g)$	Rated FAD, m^3/min	Motor rating kW	Transmission type	No of belts	Motor Speed rpm	Annual operating Hours	Remarks
	Packing House										
1	P2X10	Reciprocating	1	3 0	27 6	132	Belt	1 (flat)	1480	>5000	Operating
2	P2X11	Reciprocating	1	3 0	27 6	132	Belt	5	1480	>5000	Operating
3	P2X12	Reciprocating	1	3 0	27 6	132	Belt	5	1480	>5000	Operating
4	P2X13	Reciprocating	1	3 0	27 6	132	Belt	5	1480	<5000	Stand by
5	P2X14	Reciprocating	2	8 5	6 6	45	Belt	4	1480	<5000	Stand by
6	P2X15	Reciprocating	2	8 5	6 6	45	Belt	4	1480	<5000	Stand by
7	P2X16	Reciprocating	2	10 5	13 84	110	Belt	6	1480	>5000	Operating
	Cement Mill - 1 Area										
8	Z1U11	Reciprocating	2	5 0	31 41	160	Belt	11	2170	<5000	Stand by
9	Z1U12	Reciprocating	2	5 0	31 41	160	Belt	11	2170	<5000	Stand by
10	Z1U13	Reciprocating	2	5 0	31 41	160	Belt	11	2170	<5000	Stand by
11	Z1U15	Reciprocating	2	5 0	31 41	160	Belt	11	2170	<5000	Stand by
	Cement Mill - 2 Area										
12	Z2U11	Reciprocating	2	5 0	31 41	160	Belt	11	1480	<5000	Stand by
13	Z2U12	Reciprocating	2	5 0	31 41	160	Belt	11	1480	<5000	Stand by
14	Z2U13	Reciprocating	2	5 0	31.41	160	Belt	11	1480	<5000	Stand by
15	Z2U15	Reciprocating	2	5 0	31 41	160	Belt	11	1480	>5000	Operating

Appendix - 5/1 contd .

Sl No	ID Code	Type*	No of stages	Design pressure, kg/cm^2(g)	Rated FAD, m^3/min	Motor rating, kW	Transmission type	No of belts	Motor Speed, rpm	Annual operating Hours	Remarks
	Cement Mill - 3 Area										
16	Z3U06	Reciprocating	2	6 0	30 64	160	Belt	1 (flat)	1489	<5000	Stand by
17	Z3U07	Reciprocating	2	6 0	30 64	160	Belt	11	1489	<5000	Stand by
18	Z3U08	Reciprocating	2	6 0	30 64	160	Belt	11	1489	<5000	Stand by
19	Z3U09	Reciprocating	2	6 0	30.64	160	Belt	11	1489	>5000	Operating
20	Z3U10	Reciprocating	2	6 0	30 64	160	Belt	11	1489	<5000	Stand by
21	Z3U11	Reciprocating	2	6 0	30 64	160	Belt	11	1489	<5000	Stand by
	Cement Mill - 4 Area										
22	Z4U06	Reciprocating	2	6 0	30 64	160	Belt	11	1489	<5000	Stand by
23	Z4U07	Reciprocating	2	6 0	30 64	160	Belt	11	1489	>5000	Operating
24	Z4U08	Reciprocating	2	6 0	30 64	160	Belt	11	1489	>5000	Operating
25	Z4U09	Reciprocating	2	6 0	30 64	160	Belt	1(flat)	1489	>5000	Operating
26	Z4U10	Reciprocating	2	6 0	30 64	160	Belt	1 (flat)	1489	<5000	Stand by
27	Z4U11	Reciprocating	2	6 0	30 64	160	Belt	1 (flat)	1489	>5000	Operating
	Atox Mill Area										
28	K2U06	Reciprocating	1	2	11 58	45	Belt	4	1472	>5000	Operating
29	K2U07	Reciprocating	1	2	11 58	45	Belt	4	1472	>5000	Operating
30	K2U10	Reciprocating	1	2	11 58	45	Belt	4	1472	<5000	Stand by
31	K2U11	Reciprocating	1	2	11 58	45	Belt	4	1472	<5000	Stand by
32	K2X20	Reciprocating	2	8 5	6 6	45	Belt	4	1472	>5000	Operating
33	K2X21	Reciprocating	2	8 5	6 6	45	Belt	4	1472	>5000	Operating
34	K2X23	Reciprocating	2	8 5	6 6	45	Belt	4	1472	>5000	Operating
35	K2X24	Reciprocating	2	8 5	6 6	45	Belt	4	1472	<5000	Stand by

Appendix - 5/1 contd

Sl No	ID Code	Type*	No of stages	Design pressure, kg/cm^2(g)	Rated FAD, m^3/min	Motor rating kW	Transmission type	No of belts	Motor Speed, rpm	Annual operating Hours	Remarks
	Kiln 1 - Area										
36	W2X08	Reciprocating	2	10 5	13 81	132	Belt	3	1460	>5000	Operating
37	W2X09	Reciprocating	2	10 5	13 81	132	Belt	3	1460	<5000	Stand by
38	W2X10	Reciprocating	2	10 5	13 81	132	Belt	4	1460	>5000	Operating
	Kiln 2 - Area										
39	W2X01	Reciprocating	2	10	10 2	75	Belt	4	1475	>5000	Operating
40	H2X01	Reciprocating	2	8 5	4 44	37	Belt	4	1475	>5000	Operating
41	H2X02	Reciprocating	2	10 5	13 81	132	Belt	4	1480	>5000	Operating
42	H2X03	Reciprocating	2	8 5	6 6	37	Belt	4	1475	<5000	Stand by
	Phase 1 - Enviro Care										
43	W1X11	Screw	1	8	26 25	200	Direct	N A	-	>5000	Operating
44	W1X12	Screw	1	8	26 25	200	Direct	N A	-	>5000	Operating
45	W1X13	Screw	1	8	26 25	200	Direct	N A	-	>5000	Operating
46	W1X14	Screw	1	8	26 25	200	Direct	N A	-	<5000	Stand by
	Phase 2 - Enviro Care										
47	W2X11	Screw	1	8	26 25	200	Direct	N A	-	>5000	Operating
48	W2X12	Screw	1	8	26 25	200	Direct	N A	-	<5000	Stand by
49	W2X13	Screw	1	8	26 25	200	Direct	N A	-	>5000	Operating
50	W2X14	Screw	1	8	26 25	200	Direct	N A	-	<5000	Stand by

* All reciprocating compressors are KG Khosla make

N A Not Applicable

APPENDIX - 5/2

COMPRESSORS - FREE AIR DELIVERY (FAD) TEST

A. PUMP- UP METHOD

The actual average Free Air Delivery (FAD) capacity of an air compressor can be found by isolating the compressor and receiver from the circuit and observing the time taken for pumping-up the receiver from a lower (ambient) pressure P_s and temperature T_1 to a higher (cut off) pressure P_d and temperature T_2 By knowing the receiver volume and inter connecting pipeline volume from compressor to receiver, the free air delivery can be calculated with the following relation

$$\text{FAD } (m^3/min) = \frac{P_d}{P_s} \times \frac{T_1}{T_2} \times \frac{V}{t}$$

where, P_d = Delivery or Cut-off pressure, kg/cm^2 (a)

P_s = Suction pressure, kg/cm^2 (a)

T_1 = Air intake temperature, ° K

T_2 = Air delivery temperature,° K

V =Volume of the receiver + Volume of the inter-connecting pipeline from compressor to receiver , m^3

t = Time taken to fill the receiver, min.

RESULTS OF FAD TEST BY PUMP-UP METHOD :

FAD test by pump-up method was conducted for Packing house compressor **P2X16** as it was possible to disconnect the compressor receiver from the distribution network. The results are summarised below ·

Appendix - 5/2 contd..

Sl No	Particulars	Unit	Packing House compressor
1	ID Code		P2X16
2	Rated Capacity	(m^3/min)	13.84
3	Air Delivery Pressure	kg/cm^2 (a)	7 0
4	Air Suction Pressure	kg/cm^2 (a)	1 0
5	Air Delivery Temperature	°C	34
6	Air Suction temperature	°C	31
7	Receiver Volume (including pipe line volume)	m^3	1 01
8	Time taken to fill the receiver	sec	32
9	Actual Ave FAD	(m^3/min)	13 61
10	% FAD	%	98 3

B. SUCTION VELOCITY METHOD

- Using an ANEMOMETER, the average air velocity at the compressor suction side during compressor loading duration is measured. If required, the suction hood may be removed and the suction duct can be extended using a card board extension of same diameter to facilitate taking measurements. The free air delivery can be calculated with the following relation:

FAD (m^3/min) = (Suction air velocity in m/sec) x 60 x (Inlet duct cross section area in m^2)

Appendix - 5/2 contd.

RESULTS OF FAD TEST BY SUCTION VELOCITY METHOD :

As there is no separate receiver for each compressor and also since the process is continuous, Suction Velocity Method was adopted to arrive at the actual FAD delivered

Sl No.	ID Code	Rated FAD, m^3/min	Suction c/s area, m^2	Suction air velocity, m/s	Actual FAD, m^3/min	Percentage FAD
	Packing House					
1	P2X10	27 6	0 1849	1 642	18 22	66
2	P2X11	27 6	0 1849	2.046	22 70	82
3	P2X12	27 6	0 1849	1 888	20 95	76
	Cement Mill - 2 Area					
4	Z2U15	31 41	0 1849	3 088	34 26	109
	Cement Mill - 3 Area					
5	Z3U09	30.64	0 1849	2 862	31 80	104
	Cement Mill - 4 Area					
6	Z4U07	30 64	0.1849	2 440	27 12	89
7	Z4U08	30 64	0 1849	2 950	32 72	107
8	Z4U09	30 64	0 1849	2.460	27 25	89
9	Z4U11	30 64	0 1849	2 870	31 80	104
	Atox Mill Area					
10	K2U07	11 58	$12\ 73X10^{-3}$	9 9	7 56	65 3
11	K2U11	11 58	$12\ 73X10^{-3}$	11 13	8.49	73 3
12	K2X20	6 6	$6.36X10^{-3}$	10 45	3 99	60 5
13	K2X21	6 6	$6.36X10^{-3}$	10 24	3 91	59 2
14	K2X23	6 6	$6.36X10^{-3}$	9 94	3 80	57 6
	Kiln 1 - Area					
15	W2X08	13 81	0 1849	1 183	13 12	95 0
16	W2X10	13 81	0 1849	0 86	9 54	59 6
	Kiln 2 - Area					
17	W2X01	10 2	0 1849	0 860	9.55	93 6
18	H2X02	13 81	0 5616	0 244	8 23	60 0
	Phase 1 - Enviro Care					
19	W1X12	26 25	1.00	0 283	16 95	64 6
20	W1X13&14	26 25+26 25	1.00	0 667	40 17	76 5
	Phase 2 - Enviro Care					
21	W2X11	26 25	1 00	0 321	19 23	73 3
22	W2X13	26 25	1.00	0.396	23.76	90 5

SAVINGS ACHIEVABLE BY IMPROVING COMPRESSOR FAD

The FAD of the compressors should atleast be 85% of their rated FAD The FAD of totally 14 number of compressors (Phase - I & Phase -II together) are less than 85% Choked air filters, valve leakages, worn out piston rings and cylinder liners, etc , are the reasons for lower FAD By proper maintenance practices, the FAD could be improved to 85% The details of FAD improvement for 7 number of compressors have been given below Details for the remaining compressors are discussed in Appendix-5/8 and Appendix-5/9

Sl No	ID Code	FAD , m^3/min			Actual Power Drawn, kW	Sp Power Cons ,kW/(100 m^3/h)			Annual Operating Hours,h	Savings		
		Rated	Existing	Improved		Existing	Improved	Reduction		Power, kW	Annual Energy, lakh kWh	Annual Cost, Rs lakhs
	Atox Mill Area											
1	K2U07	11 58	7 56	9 84	27 6	6 08	4 67	1 41	3000	8 3	0 25	0 75
2	K2U11	11 58	8 49	9 84	35 4	6 95	5 99	0 96	3000	5 6	0 17	0 51
	Kiln 1 - Area											
3	W2X10	13 81	9 54	11 74	54 3	9 49	7 71	1 78	5000	12 5	0 63	1 88
	Kiln 2 - Area											
4	H2X02	13 81	8 23	11 74	74 4	15 07	10 56	4 50	4000	31 7	1 27	3 81
	Phase 1 - Enviro Care											
5	W1X13 & W1X14	52 5	40 17	44 63	369 2	15 32	13 79	1 53	6000	41 0	2 46	7 37
	Phase 2 - Enviro Care											
6	W2X11	26 25	19 23	22 31	124 0	10 75	9 26	1 48	4000	19 9	0 80	2 39
	Total									119 0	5 58	16 71

Appendix - 5/3 contd.

Total power savings	= 119 0 kW
Total annual energy savings	= 5 58 lakh kWh

Assuming 80% of the above savings can be realised

Total annual energy savings	= 4 46 lakh kWh
Total annual cost Savings (@ Rs.3 00/kWh)	= 4 46 x 3 00
	= Rs.13 38 lakhs
Investment required	= Rs 3 50 lakhs
Simple Payback Period	= $\frac{\text{Investment Required}}{\text{Annual Cost Savings}}$
	= 4 months

APPENDIX - 5/4

SPECIFIC POWER CONSUMPTION DETAILS OF COMPRESSORS

Sl No	ID Code	Rated FAD, m^3/min	Actual FAD		Rated Power, kW	Actual Power, kW	Specific Power Consumption, kW/(100 m^3/hr)	Air Delivery Pressure, $kg/cm^2(g)$
			m^3/min	m^3/h				
	Packing House							
1	P2X10	27 6	18 22	1093 2	132	72.3	6 61	2 2
2	P2X11	27 6	22 7	1362 0	132	88.5	6 5	2.2
3	P2X12	27 6	20 95	1257 0	132	92.4	7 35	2.2
4	P2X16	13 84	13 61	816 6	110	83.7	10 25	6.0
	Cement Mill - 2 Area							
5	Z2U15	31 41	34 26	2055 6	160	-	-	4 0
	Cement Mill - 3 Area							
6	Z3U09	30 64	31 8	1908 0	160	-	-	4 0
	Cement Mill - 4 Area							
7	Z4U07	30 64	27 12	1627 2	160	133 5	8 20	7 0
8	Z4U08	30 64	32 72	1963 2	160	158.4	8 07	6 5
9	Z4U09	30 64	27 25	1635 0	160	133 5	8 17	7 0
10	Z4U11	30 64	31 80	1908.0	160	158.0	8.28	7 0
	Atox Mill Area							
11	K2U07	11 58	7 56	453 6	45	27.6	6.08	0.8
12	K2U11	11 58	8 49	509.4	45	35 4	6 95	0 8
13	K2X20	6 6	3.99	239.4	45	34.5	14.41	6.2
14	K2X21	6 6	3 91	234 6	45	34 5	14.71	6.2
15	K2X23	6 6	3 80	228.0	45	35.7	15.66	6.1
	Kiln 1 - Area							
16	W2X08	13 81	13 12	787 2	132	87 0	11.05	6.0
17	W2X10	13.81	9 54	572 4	132	54 3	9 49	6.0
	Kiln 2 - Area							
18	W2X01	10 2	9.55	573.0	75	67.5	11.78	5.8
19	H2X02	13 81	8 23	493 8	132	74.4	15.07	6.6

Appendix - 5/4 contd

Sl No	ID Code	Rated FAD, m³/min	Actual FAD m³/min	Actual FAD m³/h	Rated Power, kW	Actual Power, kW	Specific Power Consumption, kW/(100 m³/hr)	Air Delivery Pressure, kg/cm²(g)
	Phase 1 - Enviro Care							
20	W1X12	26 25	16 95	1017 0	200	-	-	6 9
21	W1X13 &14	26 25+ 26 25	40 17	2410 2	200 + 200	369 2	15 32	6 9
	Phase 2 - Enviro Care							
22	W2X11	26.25	19 23	1153 8	200	124 0	10 75	7 0
23	W2X13	26 25	23 76	1425.6	200	183 0	12 84	7 0

APPENDIX - 5/5

COMPRESSORS - EFFICIENCY EVALUATION

The efficiency evaluation of all the compressors have been carried out after arriving at the theoretical power requirement s and the results are tabulated below

Theoretical power requirement for s - stage polytropic compression can be calculated from the formula

$$P = \frac{s\ k}{(k-1)} \frac{P_s . V}{6120} \left[\left(\frac{P_d}{P_s}\right)^{(k-1)/s\,k} - 1 \right]$$

where, P = Theoretical power requirement in kW

P_s = suction pressure in kg/m^2 (a)

P_d = discharge pressure in kg/m^2 (a)

V = actual FAD in m^3/min

s = number of stages

k = Polytropic index of compression for air = 1 4

The compressor efficiency is calculated as given below

$$\text{Efficiency of the compressor} = \frac{\text{Theoretical power (kW)}}{\text{Actual power (kW) x Efficiency of motor *}}$$

* Efficiency of motor is taken as 85%, if the motor loading is more than 60% and 78%, if the motor loading is less than 60%.

Appendix - 5/5 contd

Sl No	ID Code	Rated Power, kW	Actual FAD, m^3/min	Delivery Pressure, $kg/cm^2(a)$	Suction Pressure, $kg/cm^2(a)$	No of Stages	Theoretical Power, kW	Actual Power, kW	Compressor Efficiency, %
	Packing House								
1	P2X10	132	18 22	3 2	1 0	1	41 08	72 3	67
2	P2X11	132	22 70	3 2	1 0	1	51 17	88 5	68
3	P2X12	132	20 95	3 2	1 0	1	47 23	92 4	60
4	P2X16	110	13 61	7 0	1 0	2	53 85	83 7	76
	Cement Mill - 2 Area								
5	Z2U15	160	34 26	5 0	1 0	2	95 71	-	-
	Cement Mill - 3 Area								
6	Z3U09	160	31 80	5 0	1 0	2	94 05	-	-
	Cement Mill - 4 Area								
7	Z4U07	160	27 12	8 0	1 0	2	100 00	133 5	83
8	Z4U08	160	32 72	7 5	1 0	2	119 79	158.4	84
9	Z4U09	160	27 25	8 0	1 0	2	99 72	133 5	83
10	Z4U11	160	31 80	8 0	1 0	2	116 64	158 0	82
	Atox Mill Area								
11	K2U07	45	7 56	1 8	1 0	1	7 91	27 6	34
12	K2U11	45	8 49	1 8	1 0	1	8 88	35 4	30
13	K2X20	45	3 99	7 2	1.0	2	14 87	34 5	51
14	K2X21	45	3.91	7 2	1.0	2	14 57	34 5	50
15	K2X23	45	3 80	7 1	1 0	2	14 05	35 7	46
	Kiln 1 - Area								
16	W2X08	132	13 12	7 0	1 0	2	48 09	87 0	65
17	W2X10	132	9 54	7 0	1 0	2	34 97	54 3	76
	Kiln 2 - Area								
18	W2X01	75	9 55	6 8	1 0	2	34 41	67 5	60
19	H2X02	132	8 23	7 6	1 0	2	31 64	74 4	61
	Phase 1 - Enviro Care								
20	W1X12	200	16 95	7 9	1 0	1	78 03	-	-
21	W1X13&14	200+200	40.17	7 9	1 0	1	184 92	369 2	60
	Phase 2 - Enviro Care								
22	W2X11	200	19 23	8 0	1 0	1	89 24	124 0	85
23	W2X13	200	23 76	8 0	1 0	1	110 26	183 0	71

COMPRESSORS - OPERATING PARAMETERS

Sl No	ID Code	Air Delivery Pressure, $kg/cm^2(g)$	Pressure Settings, $kg/cm^2(g)$		Temperature before cooler, ^oC		Temperature after cooler, ^oC		Inlet water temperature ^oC	Outlet water temperature ^oC	
			Loading	Unloading	I Stage	II Stage	I Stage	II Stage		I Stage	II Stage
	Packing House										
1	P2X10*	2 2	2 2	2 2	125, 97	-	47	-	26	29	-
2	P2X11*	2 2	2 2	2 2	107, 110	-	56	-	27	29	-
3	P2X12*	2 2	2 2	2 2	119, 114	-	45	-	26	29	-
4	P2X16	6 0	5 0	6 0	109	107	38	39	28	30	30
	Cement Mill - 2 Area										
5	Z2U15	4	4	4	52,60	58	34,40	-	26	28	28
	Cement Mill - 3 Area										
6	Z3U09#	4	4	4	50, 64	70	30,32	-	26	27	-
	Cement Mill - 4 Area										
7	Z4U07#	7 0	7 0	7 0	76, 77	78	38, 50	-	26	27	-
8	Z4U08#	6 5	6 5	6 5	60, 70	62	41, 55	-	26	27	-
9	Z4U09#	7 0	7 0	7 0	94, 72	73	40,37	-	26	28	-
10	Z4U11#	7 0	7 0	7 0	82, 71	60	45, 38	-	26	28	-
	Atox Mill Area										
11	K2U07*	0.8	0 8	0 8	90	-	45	-	26	28	-
12	K2U11*	0 8	0 8	0 8	85	-	43	-	26	28	-
13	K2X20	6 2	5 7	5 7	84	68	32	36	27	29	28
14	K2X21	6 2	5 7	5 7	69	68	42	32	26	28	28
15	K2X23	6.1	5 9	6 1	98	82	44	33	26	29	29

* Single stage compressor

\# After-cooler is not provided

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Appendix - 5/6 contd..

Sl No	ID Code	Air Delivery Pressure, kg/cm²(g)	Pressure Settings, kg/cm²(g)		Temperature before cooler, °C		Temperature after cooler, °C		Inlet water temperature, °C	Outlet water Temperature, °C	
			Loading	Unloading	I Stage	II Stage	I Stage	II Stage		I Stage	II Stage
	Kiln 1 - Area										
16	W2X08	6 0	5 7	6 0	115	85	39	32	26	29	28
17	W2X10	6 0	5 6	6 0	90	78	45	32	27	28	28
	Kiln 2 - Area										
18	W2X01	5 8	5 4	5 8	74	80	31	28	26	28	28
19	H2X01	5 8	5.4	5 8	66	65	29	27	26	28	28
20	H2X02	6 6	6	6 5	74	101	32	29	26	28	29
	Phase 1 - Enviro Care										
21	W1X12*	6 9	6 5	6 9	-	-	-	-	-	-	-
22	W1X13*	6 9	6 5	6 9	-	-	-	-	-	-	-
23	W1X14*	6 9	6 5	6 9	-	-	-	-	-	-	-
	Phase 2 - Enviro Care										
24	W2X11*	7 0	6 5	7 0	-	-	-	-	-	-	-
25	W2X13*	7 0	6 5	7 0	-	-	-	-	-	-	-

* Single stage compressor

APPENDIX - 5/7

COMPRESSOR LOADING PATTERN

Sl. No.	ID.Code	Cycle time		% Loading
		Loading duration, seconds	Unloading duration, seconds	
	Packing House			
1	P2X10	Loaded to 100%		
2	P2X11	Loaded to 100%		
3	P2X12	Loaded to 100%		
4	P2X16	47.8	35.25	58.0
	Cement Mill - 2 Area			
5	Z2U15	Loaded to 100%		
	Cement Mill - 3 Area			
6	Z3U09	Loaded to 100%		
	Cement Mill - 4 Area			
7	Z4U07	Loaded to 100%		
8	Z4U08	Loaded to 100%		
9	Z4U09	Loaded to 100%		
10	Z4U11	Loaded to 100%		
	Atox Mill Area			
11	K2U07	Loaded to 100%		
12	K2U11	Loaded to 100%		
13	K2X20	Loaded to 100%		
14	K2X21	40 0	16.3	71.0
15	K2X23	19 8	4.0	83.2
	Kiln 1 - Area			
16	W2X08	143 3	43 7	76.6
17	W2X10	140 3	49 3	74.0
	Kiln 2 - Area			
18	W2X01	312	48	86.7
19	H2X01	Loaded to 100%		
20	H2X02	35 3	25.8	57.8

Appendix - 5/7 contd .

Sl. No.	ID Code	Cycle time		% Loading
		Loading, seconds	Unloading, seconds	
Phase 1 - Enviro Care				
21	W1X12	22 0	8 0	73 3
22	W1X13	16 5	7 0	70 2
23	W1X14	17.3	6 7	72 1
Phase 2 - Enviro Care				
24	W2X11	Loaded to 100%		
25	W2X13	Loaded to 100%		

APPENDIX - 5/8

COMPRESSED AIR DISTRIBUTION DETAILS

Compressor ID Code	Application Area	Compressor Designed Capacity		Equipment Designed Requirement		Remarks
		Volume (m^3/min)	Pressure (kg/cm^2)	Volume (m^3/min)	Pressure (kg/cm^2)	
PACKING PLANT AREA						
P2X10,	Silo Aeration	27.6	3	54.00	-	@ 6 m^3/min/ Packer for 9 packers
P2X11,	Packer Aeration	27.6	3			
P2X12	Packer top hopper aeration	27.6	3			
	TOTAL	**82.8**	-	**54.00**	-	-
P2X16	Opening valve	13.84	10.5	9.00	7	@ 1 m^3/min/Packer for 9 packers and @ 1 m^3/min/filter
	Feed valve & filters					
	Dust filters (4 Nos)			2.00		
	TPS M/C Filters (2 Nos)			0.25		
	TOTAL	**13.84**	-	**11.25**		-
CEMENT MILL - 2 AREA						
Z2U15	Water spray for CM 1 & CM-2	31.41	5	12.80	2	-
	TOTAL	**31.41**	-	**12.80**	-	-
CEMENT MILL - 3 AREA						
Z3U09	Water Spray for CM-3	30.64	6	3.80	2	-
	Dust filters					
	U2P55			0.15	7	-
	U2P56			0.15	7	-
	U2P58			0.15	7	-
	U2P59			0.15	7	-
	U2P61			0.15	7	-
	Z3P31			0.46	7	-
	Z4P21			0.46	7	-
	U1P41			0.93	7	-
	U1P61			0.15	7	-
	C1P21			0.15	7	-
	C1P31			0.15	7	-
	TOTAL	**30.64**	-	**6.85**	-	-
CEMENT MILL - 4 AREA						
Z4U07,	Water spray for CM-4	30.64	6	4.20	2	-
Z4U08,	Fluxo pump	30.64	6	119.40	-	-
Z4U09,	-	30.64	6	-	-	-
Z4U10	-	30.64	6	-	-	-
	TOTAL	**122.56**	-	**123.60**	-	-

Appendix - 5/8 contd

Compressor Eqpt No	Application area	Designed Capacity Volume (m^3/min)	Designed Capacity Pressure (kg/cm^2)	Designed Requirement Volume (m^3/min)	Designed Requirement Pressure (kg/cm^2)	Remarks
			ATOX MILL AREA - 5			
K2U07,	C P Pump	11 58	2	24 00	1 5	-
K2U11		11 58	2			
	TOTAL	23.16	-	24.00	-	-
K2X20,	Filters	6 6	8 5	-	-	-
K2X21,	K2P01	6 6	8 5	3 20	7	-
K2X23	K2P06	6 6	8 5	3 20	7	-
	K2P19			0 15	7	-
	K2013			0 20	7	-
	K2P77			0 15	7	-
	K2P61			0 20	7	-
	Pneumatic gates (10 Nos)			1 00	7	-
	TOTAL	19 80	-	8 10	-	-
			KILN - I AREA			
W2X08	Silo Extraction Flaps (7 Nos)	13 81	10 5	0 30	7	-
	Cooler dust valves			1 50	7	-
	Pneumatic gates (18 Nos)			2 25	7	0 125 Nm^3/min/gate
	Double flaps (2 Nos)			0 30	7	-
	Kiln Inlet seal (5 Nos)			0 03	7	0 005 Nm^3 Min/seal
	Gas Analysers			0 80	7	-
	Cooler water spray (6 Nos)			0 60	7	0 1 Nm^3/min /unit
	DBC Dampers			0 20	7	-
	Hoisting Damper			0 12	7	-
	Shock Blasters			1 00	7	-
	Temp Scanner			0 50	7	-
	T C Camera			0 50	7	-
	RM-1 Girth Gear Lubrication			1 50	-	-
	Connection to Air Seal at Calciner FK pump			1 00	4 2	-
	Miscellaneous			1 00	-	-
	TOTAL	13.81	-	11.60	-	-
W2X10	Filters	13 81	10 5			-
	L/S Crusher (AOPO1)			0 45	7	-
	RM Area			-	-	-
	H1P01			0 28	7	-
	H1P11			0 50	7	-
	H1P11			0 45	7	-
	H1P21			0 15	7	-
	R1P41			0 40	7	-
	R1P51			0 16	7	-
	Kiln Feed area			-	-	-
	W1P11			0 80	7	-
	W1P01			0 28	7	-
	Belt bucket elevator area			-	-	-
	W1P21			0 47	7	-
	DBC Area			-	-	-
	U1P11			0 42	7	-
	U1P21			0 80	7	-
	Coal Mill area			-	-	-

Appendix - 5/8 contd..

Compressor Eqpt No	Application	Designed Capacity Volume (m^3/min)	Designed Capacity Pressure (kg/cm^2)	Designed Requirement Volume (m^3/min)	Designed Requirement Pressure (kg/cm^2)	Remarks
			KILN - I AREA contd.			
	K1P51			2 62	-	
	K1P61			0 28	-	
	K1P41			0 15	-	
	Miscellaneous					
	TOTAL	**13.81**	-	**9.21**	-	-
			KILN - II AREA			
H2X02	Silo extraction flaps (7 Nos)	13 81	10 5	0 30	7	-
	Cooler dust valves			3 50	7	-
	Pneumatic Gates (14 Nos)			1 75	7	0 125 Nm^3/min/gate
	Double flaps (2 Nos)			0 30	7	-
	Kiln girth gear lubrication			0 30	7	-
	Kiln inlet seal (5 Nos)			0 03	7	0 005 Nm^3/min/seal
	Gas Analysers			0 80	7	-
	Cooler Water spray (6 Nos)			0 60	7	-
	DBC Dampers			0 20	7	0 1 Nm^3/min /unit
	Hoisting Damper			0 12	7	-
	T V Camera			0 50	7	-
	Temp Scanner			0 50	7	-
	Shock Blasters			1 00	7	-
	Miscellaneous			1 00	7	-
	TOTAL	**13.81**	-	**10.90**	-	-
W2X01, H2X01	Filters	11 67	8		-	
	L/SCrusher	4 44	8 5	0 60	7	-
	RM Area			-	-	-
	J2P21			0 15	7	-
	R2P31			0 15	7	--
	R2P91			0 15	7	-
	R2P11			0 46	7	-
	R2P17/71			0 15	7	-
	R2P51			0 15	7	-
	R2P41			0 47	7	-
	R2P21			0 15	7	-
	R2P08			0 30	7	-
	R2F02			0 15	7	-
	H2P01			0 87	7	-
	H2P11			0 20	7	-
	R2P61			0 15	7	-
	Kiln Feed Area				-	-
	W1P24			0 15	7	-
	W2P01			0 28	7	-

Appendix - 5/8 contd

Compressor Eqpt No/	Application	Designed Capacity		Designed Requirement		Remarks
		Volume (m^3/min)	Pressure (kg/cm^2)	Volume (m^3/min)	Pressure (kg/cm^2)	
KILN - II AREA contd .						
	Bucket elevator area					
	W2P81			0 40	7	-
	DBC Area				-	-
	U2P57			0 15	7	-
	U2P51			0 15	7	-
	U2P52			0 15	7	
	W2P21			0 85	7	-
	ATOX Mill area	-			-	-
	K2P19			0 15	-	-
	Miscellaneous			1 00	-	-
TOTAL		**16 11**	-	**6 22**	-	-
SCREW COMPRESSORS FOR PHASE - I ENVIRO CARE SYSTEM						
W1X12, W1X13, W1X14	GCT	26 25	8 0	60 07		-
	Kiln down comer	26 25	8 0	5 47		-
	Calciner down comer	26 25	8 0	8 62		-
TOTAL		**78.75**	-	**74 16**	-	-
SCREW COMPRESSORS FOR PHASE - ENVIRO CARE SYSTEM						
W2X11, W2X12, W2X13,	GCT	26 25	8 0	59 72	-	Only two compressors are -operated
	Kiln down commer	26 25	8 0	5 80	-	
	Calciner down commer	26 25	8 0	10 30	-	
TOTAL		**78 75**	-	**75 82**	-	

APPENDIX - 5/8

COMPRESSED AIR DISTRIBUTION DETAILS

Compressor ID Code	Application Area	Compressor Designed Capacity		Equipment Designed Requirement		Remarks
		Volume (m^3/min)	Pressure (kg/cm^2)	Volume (m^3/min)	Pressure (kg/cm^2)	
PACKING PLANT AREA						
P2X10,	Silo Aeration	27 6	3	54 00	-	@ 6 m^3/min/ Packer for 9 packers
P2X11,	Packer Aeration	27 6	3			
P2X12	Packer top hopper aeration	27 6	3			
TOTAL		82.8	-	54 00	-	-
P2X16	Opening valve	13 84	10 5	9 00	7	@ 1 m^3/min/Packer for 9 packers and @ 1 m^3/min/filter
	Feed valve & filters					
	Dust filters (4 Nos)			2 00		
	TPS M/C Filters (2 Nos)			0 25		
TOTAL		13 84	-	11.25		-
CEMENT MILL - 2 AREA						
Z2U15	Water spray for CM 1 & CM-2	31 41	5	12 80	2	-
TOTAL		31.41	-	12.80	-	-
CEMENT MILL - 3 AREA						
Z3U09	Water Spray for CM-3	30 64	6	3 80	2	-
	Dust filters					
	U2P55			0 15	7	-
	U2P56			0 15	7	-
	U2P58			0 15	7	-
	U2P59			0 15	7	-
	U2P61			0 15	7	-
	Z3P31			0 46	7	-
	Z4P21			0 46	7	-
	U1P41			0 93	7	-
	U1P61			0 15	7	-
	C1P21			0 15	7	-
	C1P31			0 15	7	-
TOTAL		30 64	-	6.85	-	-
CEMENT MILL - 4 AREA						
Z4U07,	Water spray for CM-4	30 64	6	4 20	2	-
Z4U08,	Fluxo pump	30 64	6	119 40	-	-
Z4U09,	-	30 64	6	-	-	-
Z4U10	-	30 64	6	-	-	-
TOTAL		122.56	-	123 60	-	-

Appendix - 5/8 contd

Compressor Eqpt No	Application Area	Designed Capacity		Designed Requirement		Remarks
		Volume (m^3/min)	Pressure (kg/cm^2)	Volume (m^3/min)	Pressure (kg/cm^2)	
			ATOX MILL AREA - 5			
K2U07, K2U11	C P Pump	11 58	2	24 00	1 5	-
		11 58	2			
	TOTAL	23 16	-	24 00	-	-
K2X20, k2X21, K2X23	Filters	6 6	8 5	-	-	-
	K2P01	6 6	8 5	3 20	7	-
	K2P06	6 6	8 5	3 20	7	-
	K2P19			0 15	7	-
	K2013			0 20	7	-
	K2P77			0 15	7	-
	K2P61			0 20	7	-
	Pneumatic gates (10 Nos)			1 00	7	-
	TOTAL	19.80	-	8.10	-	-
			KILN - I AREA			
W2X08	Silo Extraction Flaps (7 Nos)	13 81	10 5	0 30	7	-
	Cooler dust valves			1 50	7	-
	Pneumatic gates (18 Nos)			2 25	7	0 125 Nm^3/min/gate
	Double flaps (2 Nos)			0 30	7	-
	Kiln Inlet seal (5 Nos)			0 03	7	0 005 Nm^3/Min/seal
	Gas Analysers			0 80	7	-
	Cooler water spray (6 Nos)			0 60	7	0 1 Nm^3/min /unit
	DBC Dampers			0 20	7	-
	Hoisting Damper			0 12	7	-
	Shock Blasters			1 00	7	-
	Temp Scanner			0 50	7	-
	T C Camera			0 50	7	-
	RM-1 Girth Gear Lubrication			1 50	-	-
	Connection to Air Seal at Calciner FK pump			1 00	4 2	-
	Miscellaneous			1 00	-	-
	TOTAL	13.81	-	11.60	-	-
W2X10	Filters	13 81	10 5			-
	U/S Crusher (AOPO1)			0 45	7	-
	RM Area			-	-	-
	H1P01			0 28	7	-
	H1P11			0 50	7	-
	H1P11			0 45	7	-
	H1P21			0 15	7	-
	R1P41			0 40	7	-
	R1P51			0 16	7	-
	Kiln Feed area			-	-	-
	W1P11			0 80	7	-
	W1P01			0 28	7	-
	Belt bucket elevator area			-	-	-
	W1P21			0 47	7	-
	DBC Area			-	-	-
	U1P11			0 42	7	-
	U1P21			0 80	7	-
	Coal Mill area			-	-	-

APPENDIX - 5/9

OPERATING ONLY TWO LP COMPRESSORS AND REDUCING THE PRESSURE SETTING TO 1.2 kg/cm² (g) IN THE PACKING PLANT AREA

Presently three compressors, delivering air at 2 2 kg/cm² (g), are operated when 8 packers are in operation The compressors were also found to be on-load continuously

The compressed air usage areas are packer aeration, silo aeration and packer hopper aeration The pressure at the user point was checked physically and found to be 1 0 kg/cm² (g), while at the compressor point delivery pressure was 2 2 kg/cm² (g) Also, enormous amount of compressed air is wasted for body cleaning All these tappings have to be closed immediately and if required, a separate blower or a small size compressor (less pressure) can be provided for body cleaning

Hence, by closing all these tappings it is sufficient if two compressors are operated even when 8 packers are run, which is the normal condition

The actual FAD of compressors come to

Sl No	ID Code	Actual FAD (m^3/min)	% of Rated FAD
1	P2X10	18 22	66
2	P2X11	22 70	82
3	P2X12	20 95	76

By improving the FAD to 85%, two compressors are more than sufficient for this operation

Appendix - 5/9 contd..

Present power consumption of 3 compressors (2 are operated for 15 h/day & 1 for 10 h/day)	= 72.3 +88.5+ 92.4
	= 253.2 kW

1) Power savings by stopping one compressor = 72.3 kW

Annual energy savings (@ 10 h/day & 365 day/yr)	= 72.3 x 10 x 365
	= 2,63,895 kWh
Annual cost savings (@ Rs.3.00 / kWh)	= Rs.7,91,685 (say 7 91 lakhs)

2) Power savings achieved by operating two compressors (P2X11 & P2X12) at 85% FAD (23.5 m^3/min each) & at 1.2 kg/cm^2 (g) pressure :

Power requirement for the compressors (P2X11 & P2X12) can be calculated from the formula

$$P = \frac{s.k}{(k-1)} \frac{P_s\ V}{6120} \left[\left(\frac{P_d}{P_s} \right)^{(k-1)/s\,k} - 1 \right]$$

where, P = Theoretical power requirement in kW

P_s = suction pressure in kg/m^2 (a)

P_d = discharge pressure in kg/m^2 (a)

V = actual FAD in m^3/min

s = number of stages

k = Polytropic index of compression for air = 1.4

Appendix - 5/9 contd..

$$P = \frac{1 \times 1\ 4}{(1\ 4 - 1)} \quad \frac{10000 \times 23\ 5}{6120} \left[\left(\frac{22000}{10000} \right)^{(1.4-1)/(1\times1.4)} - 1 \right]$$

= 33.98 kW

Efficiency of P2X11 compressor = 68%
Assuming motor efficiency as 85%,

Power requirement of P2X11 compressor $= \dfrac{33.96}{0.85 \times 0.68}$

= 58.8 kW

Efficiency of P2X11 compressor = 60%
Assuming motor efficiency as 85%,

Power requirement of P2X11 compressor $= \dfrac{33.96}{0.85 \times 0.60}$

= 66.6 kW

Total power requirement = (58.8 + 66.6)
= 125.4 kW

Appendix - 5/9 contd..

Power savings	= [(88 5+92.4)- 125.4]
	= 55.5 kW
Annual energy savings (@ 15 h/day & 365 day/yr)	= 55.5 x 15 x 365
	= 3,03,863 kWh
Annual cost savings (@ Rs.3 00 / kWh)	= Rs 9,11,589
	= (say 9.12 lakhs)
Total cost savings (1 +2)	= 7.91 + 9.12
	= 17 03 lakhs
Cost of investment (for improving FAD for 4 compressors)	= 2.00 lakhs
Simple payback period	= 2 months

APPENDIX - 5/10

OPTIMISATION OF COMPRESSED AIR USAGE IN CEMENT MILL AREA

In cement mill area the entire usage of compressed air can be optimised since pipe conveyor is used now for cement conveying for 3 mills and fluxo pump for 1 mill (whenever Special Grade Cement is manufactured).

For mill water spray where pressure of 2 kg/cm^2(g) is only required as against the present usage of 4 kg/cm^2(g), a single stage LP compressor similar to LP compressor in packing house (P2X10 to P2X13) can be used The designed parameters for recommended compressor is 27 6 m^3/min at 3 kg/cm^2(g), 132 kW motor rating while the requirement is 20 8 m^3/min at 2 kg/cm^2(g) pressure

For filters, where high pressure is required low capacity two stage HP compressor like P2X14, P2X15 in Packing House can be used. The design parameters for recommended compressor is 6 6 m^3/min at 8.5 kg/cm^2(g), 45 kW motor rating while the requirement is 3 05 m^3/min at 7 kg/cm^2(g) pressure

So, In cement mill 1 to 3 areas, the compressors which are operating presently (Z2U15 & Z3P09) can be replaced with 1 LP and low capacity HP compressors

It is also suggested to close all tapping points in receivers or other areas where compressed air is used for body cleaning.

Appendix - 5/10 contd..

In cement mill area, the re-allotment of compressor is suggested as mentioned below .

Phase	Compressors in Operation Presently	Application	Suggestions
I	Z2U15	For cement mill 1&2 water spray and filters	To use one low pressure compressor (capacity similar to Packing House compressor P2X10-X13) for water spray for all 4 cement mills
II	Z3U09	For cement mill 3 water spray and filters	To use 1 HP compressor (capacity similar to Packing House compressor P2X14-X15) for filters of all 4 cement mills
II	Z4U07, Z4U08, Z4U09, Z4U11	For cement mill 4 water spray, for conveying special grade cement to silo through fluxo pump	To operate fluxo pump for CM IV, only when Special Grade Cement is manufactured

Power consumption by the compressors which are in operation in cement mill area

Z2U15	=	133.0
Z3U09	=	130.0
Z4U07	=	133.5
Z4U08	=	158 4
Z4U09	=	133.5
Z4U11	=	158.0

(For Z2U15 and Z3U09, measure power readings are not available and hence the power has been calculated based on FAD and pressure measurement with compressor efficiency as 80% and motor efficiency as 90%).

Cement Mill - IV compressors are to be operated only when SGC is manufactured and so present condition can be continued.

Appendix - 5/10 contd..

Power consumption of Z2U15 & Z3U09	= 263 kW

Expected power consumption from 1 LP compressor for water spray (all 4 cement mill) and 1 HP compressor for filters (all 4 cement mills).

= 51 + 29

= 80 kW

(Power readings taken from similar compressors operating in Packing House).

∴ Power savings that can be achieved by replacing compressors for water spray and filters	= 263 - 80
	= 183 kW /h
Annual energy savings (@ 24 hours/day, 330 days/year)	= 183 x 24 x 330
	= 14,49,360kWh
Annual cost savings	= Rs 43,48,080
	= Rs 43.48 Lakhs
Investment required (For 2 LP & 2 HP compressors - including spare)	= Rs.29.0 Lakhs
Simple payback period	= 8 Months

APPENDIX - 5/11

OPERATING ONLY TWO HIGH PRESSURE COMPRESSORS IN ATOX MILL AREA

Presently three high pressure compressors are operated in the Atox mill section to meet the compressed air requirements of filters and pneumatic gates. The compressed air generation and utilisation details are given below:

Compressor ID Code	Rated FAD m^3/min	Actual FAD m^3/min	% FAD	Utilisation Area	Designed Compressed air requirement, m^3/min
K2X20	6.6	3.99	60.5	1) Filters	
K2X21	6.6	3.91	59.2	K2P01	3 20
K2X22	6 6	3.80	57 6	K2P06	3 20
				K2P19	0.15
				K2P13	0 20
				K2P77	0 15
				K2P61	0 20
				2) Pneumatic gates (10 no)	1 00
Total	19 8	8.70			8 10

Compressed air requirement = 8.10 m^3/min

By improving the FAD of the above compressors to 85% and closing the body cleaning tappings, it is possible to meet the demand with two compressors itself. If required separate blower can be provided for body cleaning purpose

Compressor FAD after improvement = 0 85 x 6 6
(85% of its rated FAD)

= 5.61 m^3/min

Compressed air generation with 2 compressors = 2 x 5.61

= 11.22 m^3/min

Appendix - 5/11 contd..

By switching-off one of the compressors, say K2X23, 35 7 kW can be saved.

Annual operating days	= 330
Annual operating hours	= 330 x 24
	= 7920
Annual energy savings	= 7920 x 35 7
	= 282744 kWh
	(say 2.83 lakh kWh)
Annual cost savings (@ Rs.3 00/kWh)	= 282700 x 3.00
	= Rs 848100/-
	(say Rs. 8.48 lakhs)
Investment required (for 4 compressors)	= Rs.2.00 lakh
Simple payback period	= 3 months

APPENDIX - 5/12

USING BLOWER AIR INSTEAD OF COMPRESSED AIR FOR COAL CONVEYING TO STORAGE BIN IN ATOX MILL SECTION

At present reciprocating air compressor is used to supply the air required at C.P Pump for coal conveying to the storage bin It was learnt that the required air pressure for conveying is around 0.8 kg/cm^2. For a low pressure application like this blowers can be used to serve the purpose, as they have lower specific power consumption compared to air compressors

PRESENT SYSTEM :

Air flow rate required		= 965 m^3/h
No of compressors supplying air		= 2 (K2U07 & K2U11)
Power consumption by compressors		
	K2U07	= 27 6 kW
	K2U11	= 35 4 kW
Total power consumption		= 63 0 kW

PROPOSED SYSTEM :

Installing a Blower to supply coal conveying air

Capacity of blower required	= 965 m^3/h
Blower air pressure	= 1 kg/cm^2
Blower power consumption	= 50 kW

Appendix - 5/12 contd..

SAVINGS :

Power savings	= 13 kW
Annual energy savings (@ 18 h/day & 330 days/y)	= 13 x 18 x 330 = 77220 kWh
Annual Cost savings @ Rs.3 00 / kWh	= Rs.231660 /- (say 2.3 lakhs)
Investment required for Blower	= Rs.1,18,800 /-
Investment required for Motor (75 HP, 1440 rpm)	= Rs.75,000 /-
Total investment required	= Rs 1,93,800/- (say 2 lakhs)
Simple payback period	= 11 months

APPENDIX - 5/13

REPLACING V- BELTS OF COMPRESSOR MOTORS WITH FLAT BELTS

In most of the compressors, V-belts are used for power transmission from motor to compressor. But the wedging in and out action of the V-belts results in power loss and induces creep in the belt The power loss due to slip and creep are 3% of belt power rating and 1% of compressor absorbed power respectively. This can be avoided by replacing the V-belts with flat belts

The details of recommended belt replacements are tabulated below

Sl No	Area	ID Code	Motor Absorbed Power kW	Power Rating of Belt kW	Power Loss kW	Annual Working Hours	Annual Energy Savings lakh kWh	Belt cost Rs lakhs	Pulley cost Rs lakhs	Total cost Rs lakhs
1	Kiln-1	W2X08	87	126	4 60	8000	0 37	0 24	0 04	0 29
		W2X10	54	168	5 52	8000	0 44	0 18	0 04	0 22
		W2X09	74	180	6 08	8000	0 49	0 23	0 04	0 27
2	Kiln-2	W2X01	67	93	3 43	8000	0 27	0 23	0 04	0 27
		H2X01	24	93	3 00	8000	0 24	0 14	0 03	0 18
3	Atox Mill	K2U06	28	93	3 04	8000	0 24	0 14	0 03	0 17
		K2U07	28	93	3 04	6000	0 18	0 14	0 04	0 17
		K2U11	36	93	3 12	6000	0 19	0 17	0 04	0 21
		K2X20	35	93	3 11	8000	0 25	0 14	0 04	0 18
		K2X21	35	93	3 11	8000	0 25	0 15	0.04	0 19
		K2X23	36	93	3 12	8000	0 25	0 17	0 04	0 21
	Total *				32 05		2 44			1 91

* figures excluding stand-by compressors (W2X09 & K2U07)

Appendix - 5/13 contd..

Savings :

Total power savings	=	32.05 kW
Annual energy savings (@ Rs 3 00 / kWh)	=	2.44 lakh kWh
Annual cost savings	=	Rs.7.32 lakhs
Cost of investment	=	Rs.1 91 lakhs
Pay back period	=	3 months

APPENDIX - 6/1

H.T. MOTOR LOADING PARAMETERS

PHASE # I Sht 1 of 3

SL. No.	APPLICATION / CONNECTED EQPT.	MOTOR							% LOAD-ING
		RATED kW	MEASURED POWER PARAMETERS						
			Volts V	Amp A	Pf. Cosφ	kVA	kW	kVAr	
1	Raw mill fan (R1P05M1)	700	6600	36.7	0 75	411.0	385 5	138.0	55 1
	-do-	700	6600	48.0	0 92	556 5	411 0	375 0	58.7
2	Rotary separator	315	6540	27 4	0 85	349 0	300 0	185 0	95 2
	-do-	315	6540	32.2	0 86	367 0	312 0	192 0	99 0
3	Raw mill main motor (R1M03)	3000	6600	256 0	0 82	2981 0	2505 0	1620 0	83 5
	-do-	3000	6600	256 0	0.83	3035 0	2808 0	1684.0	93 6
4	Raw mill main motor (R1M23)	3000	6600	39 2	0 85	456 0	439 0	93 6	14 6
	-do-	3000	6600	46 0	0 98	521 0	447 0	125 0	14 9
5	Envirocare Compressor	200	6600	7 8	0.76	222.0	189 0	125 0	94 5
	-do-	200	6600	5 4	0 78	184.0	143 0	116.0	71.5
6	Cooler ESP Fan (W1P51)	425	6600	28 9	0 86	335 0	287 0	171.0	67.5
7	Cooler Fan (W1K16M1)	315	6720	20 3	0 91	234 0	213 6	95 0	67 8
8	Cooler Fan (W1K17M1)	325	6720	10 9	0 94	126 0	126.0	9.5	38 8
	-do-	325	6720	11 8	0 99	136 8	135 0	18 5	41 5
9	Coal mill motor (K1MO3)	950	6720	73 0	0.98	843 0	825 6	95 0	86 9
10	ESP Fan (J1P44)	600	6600	52 2	0 86	596 0	511 0	595 0	85 2
11	Smoke Gas Fan (J1J01)	1650	6540	150 8	0 89	1711 0	1483 0	1711 0	89 9
12	Smoke Gas Fan (J1J03)	950	6600	92 8	0 90	1059 0	949 0	1059 0	99 9
13	Compressor (W1X11)	200	6720	18 7	0 87	220 0	191 4	108 5	95 7
14	Compressor (W1X12)	200	6720	-	-	-	-	-	-
15	Compressor (W1X13)	200	6720	18 5	0 86	214 7	184 7	109 8	92 4
16	Compressor (W1X14)	200	6720	17 8	0 89	207 3	184 5	94 6	92 3

Appendix - 6/1 contd

H.T. MOTOR LOADING PARAMETERS

PHASE # II

Sht 2 of 3

SL. No.	APPLICATION / CONNECTED EQPT	MOTOR							% LOAD-ING
		RATED kW	MEASURED POWER PARAMETERS						
			Volts V	Amp A	Pf Cosϕ	kVA	kW	kVAr	
1	Raw mill separator (R2S01)	325	6720	26 4	0 66	296.2	203.0	177 1	62.5
2	Raw mill fan (R2P05)	825	6660	51.8	0 67	609 0	400.8	344 5	48.6
3	Raw mill main motor (R2M03)	5400	6720	423.6	0 90	4485 0	4420.0	2842.2	81.9
4	Screw Compressor (W2X11)	200	6700	12.5	0 78	158.0	124 0	62 0	62.0
5	Screw Compressor (W2X12)	200	6700	13.4	0 89	217.0	194.0	97.0	97.0
6	Screw Compressor (W2X13)	200	6700	12.9	0.90	203.0	183.0	91 5	91.5
7	Coal mill fan (K2T01)	600	6720	49 7	0 87	643 0	502.2	333.1	83.7
	- do -	600	6720	55.4	0 88	645.3	569.7	371.7	95.0
	- do -	600	6720	59 7	0 88	694.8	614.7	400.6	102.5
8	Coal mill motor (K2M03)	680	6660	47 2	0.93	546 2	507.0	313 9	74.6
9	Cooler ESP fan (W2P31)	600	6660	23 0	0.77	264 2	202.3	152.9	33.7
10	Smoke gas fan (J2J01)	1650	6720	149 4	0 88	1738.6	1530.0	825 8	92.7
11	Smoke gas fan (J2J03)	825	6720	67 5	0 90	786.1	707.0	341 8	85.7
12	Kiln ESP fan (J2P09)	500	6720	41 5	0 87	483.4	420 0	238 3	84.0

H.T. MOTOR LOADING PARAMETERS

CEMENT MILL # I & II

SL. No.	APPLICATION / CONNECTED EQPT	MOTOR							% LOAD-ING
		RATED kW	MEASURED POWER PARAMETERS						
			Volts V	Amp A	Pf Cosϕ	kVA	kW	kVAr	
1	Cement Mill # 1 (Z1M03)	1800	6720	168.0	0.86	1960.0	1677.0	1015.0	93.2
2	Cement Mill # 1 (Z1M23)	1800	6720	153.6	0.95	1793.0	1706.0	552.0	94.8
3	Cement Mill # 2 (Z2M03)	1800	6720	173.6	0.86	2016.0	1740 0	1017.6	96.7
	- do -	1800	6720	174 4	0.86	2023.2	1749.6	1017.6	97.2
4	Cement Mill # 2 (Z2M23)	1800	6720	159.2	0.95	1843.2	1747 2	585.6	97 1
	- do -	1800	6660	158.4	0.95	1831.2	1737 6	580.8	96.5
5	Cement Mill # 3 (Z3M03)	4000	6720	420.0	0.81	4872.0	3918.0	2892 0	98.0
	- do -	4000	6660	424.0	0.81	4890.0	3948 0	2892.0	98.7
6	Cement Mill # 4 (Z4M03)	4000	6660	348 0	0.95	4026.0	3816.0	1290.0	95.4
	- do -	4000	6720	346.0	0.95	4014.0	3810.0	1278.0	95.3

Appendix - 6/1 contd

H.T. MOTOR LOADING PARAMETERS

L.S. CRUSHER (New & old)

Sht 3 of 3

SL. No	APPLICATION / CONNECTED EQPT	MOTOR							% LOADING
		RATED kW	MEASURED POWER PARAMETERS						
			Volts V	Amp A	Pf Cosϕ	kVA	kW	kVAr	
1	Mines Crusher I/C 6 6 kV feeder	-	6540	56 1	0 78	633 6	494 4	398 4	-
	-do-	-	6540	62 1	0 82	705 6	580 8	401 3	-
	-do-	-	6600	46 9	0 73	537 6	389 8	369 6	-
	-do-	-	6600	53 3	0 80	609 6	484 8	367 7	-
	-do-	-	6600	68 6	0 86	782 4	667 2	406 6	-
2	Primary Crusher (New)	1000	6660	21 6	0 49	247 5	121 5	216 0	12 15
	-do-	1000	6600	22 1	0 54	253 5	135 9	214 5	13 59
	-do-	1000	6600	22 8	0 54	261 0	141 8	219 0	14 18
	-do-	1000	6600	22 8	0 52	261 0	134 4	223 5	13 44
	-do-	1000	6660	22 4	0 48	258 0	122 7	226 5	12 27
3	Secondary Crusher (New)	1200	6660	36 6	0 82	423 0	347 4	241 2	28 95
	-do-	1200	6600	41 4	0 83	475 2	394 2	268 2	32.85
	-do-	1200	6720	19 1	0 31	221 4	67 7	210 6	5 64
	-do-	1200	6780	24 5	0 08	286 2	24 3	284 4	2 03
	-do-	1200	6720	24 1	0 10	280 8	28 1	279 0	2 34
4	Secondary Crusher L S (Old)	1000	6720	32.0	0 85	372 0	315 0	199 5	31 50
	-do-	1000	6720	16 5	0 48	190 5	91 1	168 0	9 11
	-do-	1000	6720	14 9	0 18	172 5	31 8	169 5	3 18
	-do-	1000	6720	37 3	0 83	433 5	358 5	243 0	35 85
	-do-	1000	6720	25 8	0 75	300 0	225 0	198 0	22 50
	-do-	1000	6720	16 0	0 25	186 0	45 9	180 0	4 59
	-do-	1000	6660	19 0	0 55	220 5	120 0	184 5	12 00
	-do-	1000	6660	25 8	0 74	298 5	220 5	199 5	22 05
	-do-	1000	6660	17 0	0 64	196 5	66 0	184 5	6 60
	-do-	1000	6660	38 3	0 83	438 0	366 0	241 5	36 60
	-do-	1000	6660	38 3	0 83	442 5	366 0	247 5	36 60
	-do-	1000	6660	36 8	0 82	424 5	349 5	241 5	34 95
5	Primary Crusher L S (Old)	760	6660	31 5	0 80	361.5	289 5	217 5	38 09
	-do-	760	6600	38 0	0 83	436 5	361.5	244 5	47 57
	-do-	760	6660	43 5	0 84	501 0	423 0	270 0	55 66
	-do-	760	6660	33.0	0 81	379 5	307 5	222 0	40.46
	-do-	760	6780	16 4	0 35	192 0	66 3	180 0	8.72
	-do-	760	6780	39 5	0 83	465 0	384 0	259 5	50 53
	-do-	760	6840	21 6	0 70	255 0	1785 0	183 0	234 87
	-do-	760	6780	27 5	0 76	322 5	243 0	211 5	31 97

APPENDIX - 6/2

L.T MOTOR LOADING PARAMETERS

PHASE # I

Sht 1 of 2

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED kW	MEASURED POWER PARAMETERS					
			A	Cosϕ	V_L	kVA	kW	
1	Harrow Hyd Pump (A1L04M6) uL	37 0	29 2	0 46	410	20 8	10 3	27 7
	Harrow Hyd Pump (A1L04M6) L	37 0	48 1	0 73	410	33 8	25 5	69 0
2	Jib Belt Motor (A1L02M1)	45 0	41 0	0 27	412	28 3	6 0	13 3
3	Belt bucket elevator (R1J13M1)	110 0	130 0	0 78	416	95 1	76 5	69 5
4	Rubber belt conveyor (R1A04M1)	30 0	23 9	0 68	414	16 5	12 3	41 0
5	Rubber belt conveyor (R1A05M1)	55 0	41 7	0 68	417	30 3	21 0	38 2
6	Rubber belt conveyor (R1A03M1)	30 0	32 5	0 65	416	23 4	15 0	50 1
7	Filter fan for silo top (H1P14M1)	55 0	71 9	0 69	414	51 5	35 7	64 9
8	Bucket elevator (R1J01M1)	110 0	53 5	0 51	414	37 7	19 0	17 2
9	Dust filter fan (R1P14M1)	30 0	22 4	0 56	390	15 6	7 2	24 0
10	Dust filter fan (H1P04M1)	15 0	20 2	0 50	419	14 5	7 2	48 0
11	Dust filter fan (R1P44M1)	18 5	18 9	0 75	419	13 8	10 8	58 4
12	Dust filter fan (W1P04M1)	22 0	13 4	0 38	423	9 8	3 5	16 1
13	Filter compressor (W1X10M1)	132 0	67 9	0 50	423	50 4	24 6	18 6
14	Envirocare Pump (J1K58M1)	22 0	21 7	0 75	421	15 8	12 2	55 2
15	Air slide Blower(W1B08)	5 5	2 5	0 55	421	2 2	1 3	23 5
16	Screw conveyor (W1B03M1)	22 0	20 3	0 34	423	14 9	4 5	20 5
17	Filter fan (W1P14M1)	30 0	28 6	0 86	421	21 1	18 3	61 0
18	AHU for ESP	7 5	7 3	0 67	421	5 7	3 9	52 0
19	Kiln compressor (W1X08M1)	132 0	141 0	0 82	421	103 5	87 0	65 9
20	Kiln compressor std-by(W1X09M1)	132 0	Standby for W1X08M1					
21	Belt bucket elevator (W1A12M1)	75 0	107 0	0 83	421	76 8	63 3	84 4
22	Filter fan (W1P32M1)	30 0	33 3	0 69	419	24 7	17 2	57 3
23	Screw conveyor (W1J01M1)	45 0	46 1	0 32	419	33 8	11 2	24 9
24	Bucket elevator (W1J03M1)	90 0	85 0	0 61	419	64 2	45 6	50 7
	- do -	90 0	105 0	0 74	419	73 8	50 7	56 3
25	Bucket elevator std-by(W1J04M1)	90 0	Standby for WIJ03M1					
26	Blower for new bin (W1A65M1)	30 0	22 8	0 58	421	16 8	9 9	33 0
27	Blower for new bin (W1A75M1)	30 0	Standby for W1A65M1					
28	Envirocare Pump (J1K17M1)	55 0	64 2	0 87	421	47 3	41 8	75 9
29	Blower for old bin(H1H09M1)	22 0	17 9	0 69	421	13 8	9 9	45 0
30	Screw conveyor (W1A03M1)	22 0	12 3	0 38	423	8 8	2 9	13 1
31	Screw conveyor (J1U43M1)	30 0	16 5	0 27	424	11 9	3 0	10 0
32	Screw conveyor (J1U41M1)	30 0	17 4	0 48	421	12 6	5 9	19 5
33	Screw conveyor (J1U42M1)	22 0	14 4	0 34	419	10 5	3 0	13 6
34	ESP drag chain (J1P53M1)	7 5	9 2	0 60	421	6 6	4 2	56 0
35	DBC Blower	30 0	26 8	0 45	421	19 3	8 9	29 5
36	DBC (U2J03)	45 0	49.3	0 70	419	38 7	28 8	63 9

Appendix - 6/2 contd

L.T. MOTOR LOADING PARAMETERS

PHASE # I

Sht 2 of 2

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosϕ	V_L	kVA	kW	
37	DBC (U2J05)	55 0	49 2	0 40	419	34 5	13 5	24 5
38	DBC (U2J04)	45 0	30 6	0 39	421	22 3	7 2	16 1
39	DBC (U2J06)	55 0	67 0	0 68	421	54 0	48 0	87 3
	- do -	55 0	105 0	0 85	421	75 0	60 0	109 1
40	RBC (L1U12)	18 5	19 9	0 59	417	7 8	4 9	26 4
41	AHU Coal Mill Room	15 0	18 0	0 70	416	12 9	11 1	74 0
42	DBC Vent fan 1	30 0	20 0	0 59	419	14 7	9 6	32 0
43	DBC Vent fan 2	30 0	34 0	0 40	428	26 1	9 6	32 0
44	RBC (L1U13)	15 0	18.6	0 70	426	26 1	10.5	70 0
45	FK Pump (K1U41)	37 0	26 9	0 39	423	19 8	6 0	16 2
46	CP Pump (K1U44)	30 0	18 6	0 22	426	13 8	2 7	8 9
47	Primary air fan (W1V07)	110 0	106 7	0 67	419	78 0	55 8	50 7
48	Drag chain (W1K08)	30 0	18 5	0 90	417	11 1	7 1	23 8
49	Fan for air seal (W1K30)	45 0	58 9	0 50	421	41 7	22 2	49 3
50	Hammer Mill (W1M01)	150 0	104 0	0 29	423	77 7	17 1	11 4
51	Coal Mill separator fan(K1P56)	200 0	320 0	0 75	430	208 5	166 2	83 1
52	Filter Compressor (W1X10) uL	132 0	65 0	0 58	419	47 4	25 5	19 3
	Filter Compressor (W1X10) L	132 0	134 0	0 85	419	98.7	54 3	41 1
53	Filter fan (K1P63)	15 0	14 2	0 63	428	10.3	6 6	44 0
54	FK Pump Blower (W1U43)	160 0	123.0	0 80	428	90 0	73 8	46 1
55	FK Pump Blower (W1U42)	160 0	Standby for W1U43					
56	CP Pump Blower (W1U46)	150 0	96 0	0 84	428	67 8	56 7	37 8
57	CP Pump Blower (W1U45)	150 0	Standby for W1U46					
58	Dust filter fan (U1P14M1)	45 0	55 0	0 56	421	40 2	24 6	54 7
59	ESP drag chain (J1P54M1)	11 0	9 2	0 60	423	6 7	4 2	37 9
60	ESP drag chain (J1P55M1)	11 0	8 7	0 51	419	6.6	4 1	37 6
61	ESP drag chain (J1P52M1)	11 0	8 4	0 59	423	6 4	3 9	35 5
62	Cooler fan (W1K10)	225 0	124 0	0 65	421	90 6	63 5	28 2
63	Cooler fan (W1K11)	225 0	154 0	0 81	424	83 7	54 9	24 4
64	Cooler fan (W1K12)	225 0	139 0	0 87	423	70 8	48 0	21 3
65	Cooler fan (W1K13)	225 0	142.0	0 87	435	75 9	49 8	22 1
66	Cooler fan (W1K14)	225 0	161 0	---	421	116 4	74 4	33 1
67	Cooler fan (W1K15)	225 0	143.7	---	421	105.9	68 7	30 5

APPENDIX - 6/3

L.T MOTOR LOADING PARAMETERS

PHASE # II

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED kW	MEASURED POWER PARAMETERS					
			A	Cosϕ	V_L	kVA	kW	
1	Harrow Hyd Pump (A204M7)	37 0	41 4	0 55	414	28 8	15 9	43 0
2	Rubber belt convevor (R2L06M1)	55 0	17 4	0 73	435	13 1	9 8	17 7
3	Rubber belt conveyor (R2A04M1)	30 0	22 2	0 76	438	16 7	12 9	43 0
4	Rubber belt conveyor (R2A05M1)	55 0	43 5	0 60	436	32 7	19 9	36 2
5	Rubber belt convevor (R2A02M1)	30 0	19 6	0 51	436	14 5	6 6	22 0
6	Rubber belt convevor (R2A06M1)	30 0	13 8	0 83	438	10 4	9 2	30 7
7	Sluicing belt convevor(R2A07M1)	7 5	10 2	0 63	436	7 9	4 6	61 6
8	Bucket elevator (R2J02M1)	110 0	67 8	0 44	436	51 5	18 6	16 9
9	Bucket elevator (R2J01M1)	110 0	Standby for R2J02M1					
10	Compressor (H2X03)	37 0	44 8	0 70	431	33 3	24 2	65 4
11	Compressor (H2X02) uL	132 0	57 0	0 37	431	42 3	13 8	10 5
	Compressor (H2X02) L	132 0	122 0	0 82	431	90 9	74 4	56 4
12	Bucket elevator (R2J13M1)	110 0	143 0	0 73	433	106 8	82 5	75 0
13	Dedusting fan (H2P12)	9 3	9 0	0 44	431	7 6	3 5	37 1
14	Screw conveyor (R2U11)	55 0	35 6	0 45	428	26 4	9 9	18 0
15	(R2U14)	5 5	7 2	0 61	428	5 7	3 6	65 5
16	(R2U13)	5 5	8 4	0 78	433	6 4	4 9	88 4
17	Silo aeration blower(H2H02)	15 0	16 1	0 69	430	11 8	7 5	50 0
18	Air compressor (W2X01) uL	75 0	41 8	0 68	431	31 4	18 9	25 2
	- do - L	75 0	102 0	0 88	431	78 0	67 5	90 0
19	Silo aeration blower(H2H03)	15 0	13 5	0 66	430	9 9	6 6	44 0
20	Silo aeration blower(H2H04)	15 0	14 1	0 70	430	10 4	6 9	46 0
21	Screw conveyor (W2A05M1)	22 0	12 5	0 48	431	9 5	3 9	17 7
22	Rotary aeration blower (W2U02)	30 0	232 8	0 82	424	17 6	14 3	47 5
23	Rotary aeration blower (W2U01)	30 0	Standby for W2U02					
24	Fan jet pulse filter(W2P02)	18 5	19 3	0 59	428	14 4	8 7	47 0
25	Screw conveyor(W2B05M1)	30 0	18 6	0 56	424	14 1	7 5	25 0
26	Belt bucket elevator(W2J03)	110 0	158 0	0 83	426	115 8	97 5	88 6
27	air slide blower(W2J01)	5 5	6 3	0 64	424	4 7	2 7	49 1
28	Drag chain conveyor(J2P12)	7 5	8 4	0 45	424	6 0	2 2	29 2
29	Air jetpulse filter(R2P92)	11 0	11 3	0 67	431	8.4	5 9	53 7
30	Drag chain conveyor(J2P14)	7 5	8 4	0 60	421	6 5	2 1	27 6
31	Pneumatic screw pump(W2U01)	45 0	30 0	0 63	424	22 0	13 5	30 0
32	Pneumatic screw pump(W2U03)	37 0	28 4	0 37	424	21 1	6 8	18 5
33	Rotary blower (W2U09)	132 0	159 0	0 84	424	118 5	102.3	77 5
34	Rotary blower (W2U04)	110 0	87 8	0 70	424	64 2	46 2	42 0
35	Primary air fan(W2V07)	90 0	99 3	0 77	421	72.0	58 1	64 5
36	Drag chian conveyor(W2K50)	7 5	6 9	0.53	431	5 2	3 2	42.4

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L T MOTOR LOADING PARAMETERS

PHASE # II

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosϕ	V_L	kVA	kW	
37	Pump water injector(W2K54)	7 5	4 9	0 81	428	6 3	5 1	68 0
38	Compressor (K2U10)	45 0	56 9	0 80	421	43 2	35 4	78 7
39	Compressor (K2X21)	45 0	56 4	0 80	435	39 2	34 5	76 7
40	Compressor (K2X20)	45 0	53 6	0 82	435	40 2	34 5	76 7
41	CP Pump compressor(K2U06)	45 0	43 0	0 74	435	33 0	27 6	61 3
42	atox mill Hyd system(K2M07)	7 5	11 6	0 32	438	9 1	4 4	58 4
43	Filter fan (K2P81)	37 0	27 8	0 45	433	20 1	6 1	16 4
44	Dyn separator(K2P74)	90 0	35 0	0 92	433	27 8	22 2	24 7
45	DBC fan(W2P26)	37 0	38 5	0 66	424	28 3	19 4	52 5
46	W2K30	45 0	51 7	0 86	426	38 2	31 9	70 9
47	Cooler fan (W2K10)	132 0	75 6	0 62	421	56 7	38 0	28 8
48	Cooler fan (W2K11)	225 0	166 0	0 76	424	120 6	96 0	42 7
49	Cooler fan (W2K12)	225 0	160 0	0 74	414	115 8	87 9	39 1
50	Cooler fan (W2K13)	225 0	119 8	0 81	424	87 3	75 6	33 6
51	Cooler fan (W2K14)	132 0	130 0	0 79	430	96 3	79 5	60 2
52	Cooler fan (W2K15)	132 0	181 0	0 86	421	132 0	114 9	87 0
53	Cooler fan (W2K16)	225 0	231 0	0 83	430	177 0	152 1	67 6
54	Cooler fan (W2K17)	132 0	134 0	0 84	419	97 2	84 0	63 6
55	Hammer mill(W2M01)	190 0	86 9	0 45	428	64 5	15 6	8 2
56	K2S03	225 0	222 0	0 74	426	170 1	122 4	54 4
57	Jet pulse filter fan (H2P02)	45 0	47 1	0 76	433	35 4	28 2	62 7
58	Filter fan (J2P24)	11 0	11 2	0 60	431	8 4	5 5	50 2
59	Air lift blower (H2H08)	132 0	77 3	0 66	431	57 6	41 4	31 4
60	air lift blower (H2H09)	132 0	93 4	0 63	433	67 2	43 5	33 0
61	H2H03	37 0	42 7	0 66	424	31 2	22 8	61 6
62	H2X02	132 0	127 0	0 73	426	95 7	78 3	59 3
63	GRS blower (J2J01A)	5 5	8 8	0 80	419	6 7	5 6	102 0
64	GRS blower (J2J01B)	5 5	9 0	0 77	419	6 6	5 1	92 7
65	GCT water pump(J2K18)	55 0	76 7	0 88	424	55 2	49 2	89 5
66	Filter fan (W2P82)	37 0	36 8	0 66	426	27 3	18 0	48 6
67	Env pump(W2K57)	22 0	24 3	0 80	423	17 8	15 1	68 5
68	SOVR pump No 2	15 0	20 5	0 79	424	15 0	12 6	84 0
69	Water pump 1(R2X50)	30 0	45 1	0 78	416	28 8	23 1	77 0
70	Water pump 1(R2X52)	30 0	48 5	0 85	416	34 7	30 1	100 2
71	CT pump Ph 1 (R2X61)	5.5	5 6	0 17	423	4 2	1 5	27 3
72	Pump 2 for Raw mill(R2X65)	7 5	11 7	0 86	419	8 6	7 1	94 8
73	Pump 1 for gas analyser(W2W46)	11 0	18 2	0 72	419	13 5	9 9	90 0

Appendix - 6/3 contd..

L.T. MOTOR LOADING PARAMETERS

PHASE # II

Sht 3 of 3

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosϕ	V_L	kVA	kW	
74	K2A04	12 5	11 4	0 29	436	8.6	1.7	13 9
75	K2A03	15 0	12 0	0.39	436	9.3	3.3	22 0
76	compressor(K2U07)	45 0	56 6	0 60	438	42.3	28.2	62 7
77	Compressor(K2U11)	45 0	59 9	0 78	452	47 3	39.0	86 7
78	DBC (U2J03)	45 0	39 5	0 60	421	28.8	17.7	39.3
79	Pneumatic conveyor(K2U05)	75 0	46 0	0.60	424	30.9	18 6	24 8
80	Filter fan(K2P63)	15 0	10.9	0.82	426	8.0	6 6	44 0
81	Compressor (K2X24) L	45.0	58 0	0.82	431	43 8	35 7	79 3
	-do- uL	45 0	20 0	0 34	431	0 0	6.9	15 3
82	Screw conveyor(W2P18)	11 0	7 2	0.96	423	5 3	4 8	43 6
83	DBC fan for dust filter(W2P26)	37 0	38 5	0 62	433	28 9	18.3	49 5
84	Compressor(H2X03)	37 0	45 3	0 68	435	33 7	24.3	65 7
85	Jet pulse fan filter(R2P14)	30 0	28 5	0 40	433	21 4	7 3	24 2

APPENDIX - 6/4

L.T. MOTOR LOADING PARAMETERS

OLD L.S. CRUSHER & COAL CRUSHER

SL. No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosϕ	V_L	kVA	kW	
	Old L.S. Crusher							
1	RBC 1 B	110 0	119 0	0 79	423	76 8	68 4	62 2
2	Dust filter fan (A0P04)	75 0	104 0	0 71	431	77 7	57 9	77 2
3	Hydraulic Main pump (A0M03)	75 0	15 1	0 32	431	11 3	2 8	3 7
4	RBC 401 B	110.0	107 0	0 53	421	72.6	49 5	45 0
5	RBC 404	75 0	63 9	0 74	421	61 2	36 6	48 8
7	RBC 401 A	15 0	109 0	0 76	421	71 4	82 5	550 0
	New L.S. Crusher (Mines)							
1	Conveyor belt (A3J04M1)	90 0	65 0	0 27	445	53 1	14 4	16 0
	- do -	90 0	98 0	0 74	428	75.0	57 9	64 3
2	Conveyor belt (A3J04M2)	90 0	82 0	0 28	445	63 6	17 1	19 0
	- do -	90 0	109 0	0 70	433	80 7	60 0	66 7
3	Conveyor - B (A3J04M3)	90 0	65 2	0 36	445	53 4	17 4	19 3
	- do -	90 0	119 0	0 77	428	89 4	73 5	81 7
4	Scraper chain (A3J02)	3 7	4 3	0 29	431	3 1	1 2	32 4
5	Cooling fan for DC Motor (A3J01M1)	7 5	6 4	0 84	435	4 9	4 5	60 0
6	Cooling fan for DC Motor (A3J01M2)	7 5	6 2	0 88	435	4 5	4 5	60 0
7	dust filter fan (A3P04)	132	123	0 75	431	90 6	72 6	55 0
8	Compressor uL	30	23 4	0 22	435	17 1	3 6	12 0
	- do - L	30	33 4	0 68	435	24 9	16 8	56 0
9	Blower (A3M01X1)	7 5	9 7	0 63	445	7 6	5 4	72 0
10	Conveyor - A (A3j03I1)	30	26 7	0 57	435	20 1	11 4	38 0
11	Apron feeder (for 90kW DC Motor)	90	116	0 69	435	84 3	38 4	42.7
	- do -	90	127	0 73	435	94 2	46 8	52 0
12	Screw conveyor (A3P05)	5.5	4 8	0 15	433	3 7	1 2	21 8
13	Water Pump for Comp (A3W01)	5 5	5 8	0 77	438	4 4	3 9	70 9
	Coal Crusher							
1	RBC (L1L01)	75 0	60 2	0 55	428	44 2	25 7	34 2
2	Primary chain reclaimer(chain 1)	37 0	31 2	0 52	419	20 7	11 7	31 6
3	Secondary chain reclaimer(ch-2)	18 5	14 3	0 50	419	10 1	5 3	28.5
4	RBC L1U06	11 0	9 7	0 56	431	7 1	4 9	44 2
5	RBC L1U07	11 0	7 0	0 56	431	5 1	3 0	27 0
6	Coal sec. crusher (G2M13)	132 0	31 0	0 55	426	21 8	12 6	9 5
7	Coal Pri crusher 1 (G2M03)	75 0	24 0	0 72	426	17 1	11 1	14 8
8	Pri crusher 2 (G2M23)	75 0	21 4	0 77	426	15 3	12 9	17 2
9	RBC (G2J04)	37 0	22 9	0 84	426	18 0	16 0	43.2
10	Apron feeder (G2J01)	30 0	21 5	0 56	426	15 6	5 7	19 0
11	RBC (G2J05)	30 0	21 0	0 44	428	17 3	7 8	26 0
12	RBC (G2J03)	5 5	7 3	0 52	426	5 6	2 7	49.1

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L.T. MOTOR LOADING PARAMETERS

CEMENT MILL / PUMP HOUSE PHASE # I & II

Sht 1 of 2

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosϕ	V_L	kVA	kW	
1	Compressor (Z1U11) L	160 0	231 9	0 90	415	168 9	152 4	95 3
	-do- uL	160 0	79 0	0 65	418	57 6	40 2	25 1
2	Compressor (Z1U13) L	160 0	228 6	0 89	434	177 0	160 8	100 5
	-do- uL	160 0	72 7	0 60	438	61 5	36 3	22 7
3	Elevator (Z1U01M1)	18 5	16 7	0 56	419	12 6	8 4	45 4
	-do-	18 5	18 2	0 71	419	16 5	10 2	55 1
4	Screw conveyor (Z1M11)	15 0	9 9	0 34	419	7 2	2 6	17 2
5	Fan for ESP (Z1P05)	30 0	31 7	0 66	417	22 8	16 4	54 8
6	Filter fan (Z1P11)	30 0	27 2	0 83	414	19 6	9 2	30.8
7	Screw conveyor (C1M12)	90 0	52 8	0 30	419	38 4	11 4	12 7
8	H E Motor(Z1M03)	5 5	6 0	0 53	419	4 3	3 0	54 0
9	ESP Screw conveyor (Z1P12)	5 5	4 6	0 30	414	3 2	1 1	20 7
10	Compressor (Z2M13)	45 0	11 5	0 69	414	24 7	17 0	37 8
11	Pump No 2	30 0	46 3	0 84	409	32 7	27 8	92.5
12	Pump No 6	30 0	42 3	0 82	407	29 7	25 1	83 5
13	Pump No 5	11 0	16 4	0 77	4027	11 7	9 3	84 5
14	Pump No 8	30 0	39 0	0 72	414	27 9	21 2	70 8
15	Pump No 9	30 0	38 2	0 81	407	27 0	22 2	74 0
16	Return Pump No 2	30 0	30 9	0 69	410	21 9	15 7	52 4
17	Return Pump No 3	30 0	36 6	0 90	409	26 1	23 4	78 0
18	Return Pump No 1	30 0	28 1	0 70	4048	19 8	14 7	49 0
19	cooling blower(Z2M23)	5 5	7 4	0 53	433	5 6	3 6	65 5
20	Bucket elevator(Z2U01)	18 5	16 6	0 70	433	13 6	11 0	59 7
21	New ESP Fan (Z2P07)	110 0	118 0	0 75	430	88 8	67 2	61 1
22	H E Motor(Z2M03M2)	5 5	7 7	0 55	431	5 8	3 6	65 5
23	ESP Screw conveyor (Z2P12)	5 5	4 2	0 30	430	3 1	0 6	10 9
24	Screw conveyor(Z2M11)	15 0	11 5	0 32	431	8 7	2 7	18 0
25	Fan motor (Z2S23)	200 0	276 0	0 61	423	201 0	138 0	69 0
26	ESP fan MT 71S(Z3P05)	37 0	56 2	0 75	430	41 7	34 2	92 4
27	Screw conveyor(Z3M11)	15 0	6 0	0 31	433	6 9	2 7	18 0
28	Bucket elevator(Z3U01)	22 0	17 3	0 66	431	10 2	9 6	43 6
	-do-	22 0	19 7	0 72	431	14 7	10 2	46 4
29	ESP Screw conveyor (Z3P12)	5 5	3 3	0 30	426	2 5	0 7	12 5
30	Motor cooling(Z3X73)	3 0	5 1	0 39	426	3 7	2 3	77 0
31	Bucket elevator(Z4J01)	75 0	40 0	0 64	424	35 4	26 1	34 8
	-do-	75 0	54 0	0 80	424	38 1	27 0	36 0
32	Screw conveyor(Z4M11)	30 0	21 3	0 30	424	15 8	3 8	12 5
33	Dedusting filter fan (Z4P23)	30 0	17 9	0 44	424	13 1	6 3	21 1

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L.T. MOTOR LOADING PARAMETERS

CEMENT MILL / PUMP HOUSE PHASE # I & II

Sht 2 of 2

SL No	APPLICATION / CONNECTED EQPT.		MOTOR						% LOADING
			RATED	MEASURED POWER PARAMETERS					
			kW	A	Cosϕ	V_L	kVA	kW	
34	Z4P12		5 5	3 9	0 30	424	2 9	1 0	18 5
35	ESP fan (Z4P05)		37 0	39 3	0 69	424	29 3	22 5	60 8
36	Z4C02		5 5	77 3	0 20	423	5 3	1 5	26 7
37	Z4X74		3 0	4 9	0 42	423	3 6	2 5	82 0
38	L1U11		18 5	14 4	0 48	424	11 4	9 3	50 3
	-do-		18 5	16.6	0 63	424	12 9	10 2	55 1
39	Compressor (Z3U06)	L	160 0	224 6	0 88	433	169 2	151 8	94 9
	-do-	uL	160 0	-	-	-	-	-	-
40	Compressor (Z3U08)	L	160.0	222 4	0 89	430	160 8	144 0	90 0
	-do-	uL	160 0	64 2	0 64	430	47 6	33 6	21 0
41	Compressor (Z3U11)	L	160 0	227 0	0 91	433	162 6	151 2	94 5
	-do-	uL	160 0	73 4	0 73	433	53 6	40 2	25 1

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L.T. MOTOR LOADING PARAMETERS

PACKING PLANT - PHASE # I & II

Sht 1 of 2

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosφ	V_L	kVA	kW	
	MCC - 5.1							
1	Bucket elevator (P2J31) - P7	22 0	19 0	0 57	416	13 5	7 8	35 3
	-do-	22 0	23 0	0 79	416	16 5	13.1	59 5
2	Jet Pulse filter fan(P2P23) - P7	22 0	23 6	0 76	416	17 1	13 8	62.7
3	Compressor (P2X11)	132 0	145 0	0 84	419	103 8	88.5	67 0
4	Extraction screw conveyor(P2J03)	22 0	18 0	0 66	421	13 5	9 4	42.8
5	Extraction screw conveyor(P2J02)	11 0	7 6	0.44	416	5 7	3.0	27 3
6	Jet Pulse filter fan(P2P23) - P6	22 0	26 0	0 79	417	18.6	15 3	69 5
7	Compressor (P2X12)	132 0	172.0	0.89	414	105.6	92.4	70 0
8	Compressor (P2X14)	45 0	48 7	0 76	421	35.4	28 2	62 7
9	Bucket elevator(P2J21) - P6	22 0	11 2	0 44	417	7 8	2.7	12 1
	MCC - 5.2							
10	Compressor (P2X13)	132 0	143 6	0 89	419	100 2	95 4	72.3
11	Extraction screw conveyor(P2J05)	11 0	6 2	0 24	423	4.6	1 2	10 9
12	Compressor (P2X15)	45.0	17 8	0 79	416	19 5	16 2	36 0
13	Bucket elevator(P2J61) - P10	22 0	17 0	0 53	419	13 5	9.6	43 6
	-do-	22 0	21 0	0 61	419	14 7	10.5	47 7
14	Bucket elevator(P2J51) - P9	22 0	10 0	0.28	424	8 7	1 5	6 8
15	Bucket elevator(P2J41) - P8	22 0	15 5	0.55	416	11 1	6 6	29 9
	-do-	22 0	17 2	0.72	416	12 6	9 3	42 3
16	Jet Pulse filter fan(P2P43) - P8	22 0	25 1	0.80	423	18.3	15 3	69 5
17	Jet Pulse filter fan(P2P53) - P9	22 0	29 5	0.74	416	21.3	15 6	70 9
18	Rotary control screen (P2S51)	3.7	2.1	0.30	424	3 1	0.5	13 0
19	Jet Pulse filter fan(P2P63) - P10	22 0	23 2	0.76	423	17.0	13.7	62.0
20	Extraction screw conveyor(P2J06)	11 0	7 1	0 40	421	5.3	2.5	22.6
21	Extraction screw conveyor(P2J04)	22 0	13 5	0 45	423	9.9	5.7	25.9
	MCC - 5.3							
22	Main RBC (P2U62) - P10	11 0	4.5	0 30	417	3.4	1 4	12.3
23	Bottom RBC (P2U56) - TLS No 9	11 0	4 5	0.30	421	3.1	1 2	10 9
24	Top RBC (P2U55) - TLS No 9	15 0	10.4	0.28	423	7.6	2.8	18 8
25	Rly sideBottom RBC (P2U44) No 6	18 5	7 0	0 60	421	7 6	4 2	22.7
26	Rly sideBottom RBC (P2U54) No 5	18 5	9 8	0.66	416	7 2	4 5	24 3
	-do-	18 5	10 8	0 70	416	7.6	5 2	27 9
27	Rly side Top RBC (P2U43) No 6	15 0	10.3	0.27	423	7.5	2.4	16.0
28	Rly side Top RBC (P2U53) No.5	15 0	10.5	0.27	419	7 9	2.7	17 8
	-do-	15 0	11.8	0.37	419	8.7	3.0	19.8

Appendix - 6/6 contd

L.T. MOTOR LOADING PARAMETERS

PACKING PLANT - PHASE # I & II

Sht 2 of 2

SL No	APPLICATION / CONNECTED EQPT	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosϕ	V_L	kVA	kW	
	MCC - 5.4							
29	Compressor (P2X16) L	110 0	150 0	0 71	423	111 6	83 7	76 1
	uL	110 0	87 6	0 37	424	64 8	23 1	21 0
30	Silo No 5 (P2P67)	22 0	21 0	0 66	424	16 2	10 9	49 6
31	Silo No 6 (P2P69)	22 0	26 0	0 80	424	19 7	14 9	67 5
32	Compressor (P2X10)	132 0	122 0	0 80	426	90 0	72 3	54 8
33	TPS Vacuum cleaner		117 2	0.83	424	85 5	70 5	
	Ph -1 MCC - 5.1							
34	Silo no 3 (Dust filter fan PH 1)	30 0	17 6	0 42	431	12 9	4 4	14 6
35	Dust filter fan P 3	22 0	20 8	0 80	421	15 1	12 4	56 2
36	Dust filter fan P 4	22 0	20 7	0 82	419	14 9	12 3	56 0
37	Silo no.1 (Silo top filter fan PH 1)	15 0	14 8	0.40	430	11 0	4 0	26 8
38	Bucket elevator (P1J11) P 1	22 0	22 1	0 37	423	12 9	2 3	10 5
	-do-	22 0	26 0	0 48	423	7.5	3 6	16 4
39	Bucket elevator P 2	22 0	15 7	0 18	421	12.5	2 2	9 8
40	Extraction Screw conveyor (P 2)	22 0	19 3	0 48	417	14 0	7 9	35 7
41	Extraction Screw conveyor (P 3)	22 0	21 0	0 52	419	15 9	10 1	45 7
42	Extraction Screw conveyor (P3)	22 0	16.0	0 60	419	11 1	7 2	32.7
43	Bucket elevator P4	22 0	11 2	0 22	416	8 0	1 5	7 0
44	Dust filter fan P 1	22 0	21 7	0 75	419	15 7	12 2	55 6
45	Dust filter fan P 2	22 0	25 3	0 75	417	18 2	14 7	66 8
	Ph -1 MCC - 5.2							
46	Low speed Pipe conveyor (C2P01)	90.0	60 3	0 59	433	45 3	28 8	32 0
47	Low speed Pipe conveyor (C1P01)	90 0	47 5	0 60	433	35 4	23 4	26 0
48	Bin aeration blower	15 0	9 1	0 57	431	6 8	4 3	28 8
49	Bin aeration blower Ph 2 (C2U01)	15 0	8 0	0 64	430	7 0	4 3	28 8

APPENDIX - 6/7

ENERGY SAVINGS ON CONVERSION TO STAR MODE OF OPERATION

CASE STUDY :

Application :	**Dust Filter Fan (R1P14M1)**
Rated kW	= 30 kW
Measured kW	= 7 20 kW
% Loading	= 24%
Efficiency old (Eff_{old}) (Operating efficiency)	= 70 16%
Operating loss	= { 1 - Eff_{old} } x Measured kW
	= 2.15 kW

In star mode, 20% of these losses can be saved

Therefore saving in losses	= 0 43 kW
Annual operating hours	= 8000 hours
Annual energy savings	= 3437 kWh
Cost of energy saving	= Rs 10312/- @ Rs.3 00/kWh

Similar computation for various motors to be connected in star has been carried out. Appendix - 6/7A represents the techno-economics for various motors on conversion to star mode of operation

Appendix - 6/7 contd

ENERGY SAVING IN L T DRIVES ON CONVERSION TO STAR MODE OF OPERATION FROM PRESENT D O L MODE

SL. No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED KW	FULL LOAD EFFIC (η)	FULL LOAD POWER	OPERT LOSSES IN kW	SAVINGS IN LOSSES kW	OPERT. HOURS	ANNUAL SAVINGS kWH	COST SAVINGS Rs
A	**PHASE # I**									
1	Dust filter fan (R1P14M1)	30 0	7 20	0 85	35 29	2 15	0 43	8000	3437	10312
2	Air slide blower(W1B08)	5 5	1 30	0 85	6 47	0 39	0 08	8000	629	1887
3	Screw conveyor (W1B03)	22 0	4 50	0 85	25 88	1 55	0 31	8000	2477	7431
4	Screw conveyor (W1J01)	55 0	11 20	0 85	64 71	3 87	0 77	8000	6190	18569
5	Blower for new bin (W1A65)	30 0	9 90	0 85	35 29	2 27	0 45	8000	3632	10896
6	Screw conveyor (W1A03)	22 0	2 90	0 85	25 88	1 51	0 30	8000	2409	7226
7	DBC Blower filter fan	30 0	8 90	0 85	35 29	2 22	0 44	8000	3553	10658
8	FK Pump (K1U41)	30 0	6 00	0 85	35 29	2 11	0 42	8000	3371	10112
9	CP Pump (K1U44)	30 0	2 70	0 85	35 29	2 03	0 41	8000	3250	9749
10	CP Pump Blower (W1U46)	150 0	56 70	0 85	176 47	11 75	2 35	8000	18805	56415
							SUB TOTAL =		**28947**	**143255**
B	**PHASE # II**									
1	Filter fan (K2P81)	37 0	6 10	0 85	43 53	2 56	0 51	8000	4097	12291
2	Coal belt conveyor(K2A03)	15 0	3 30	0 85	17 65	1 06	0 21	8000	1701	5104
3	Screw conveyor (K2A04)	12 5	1 70	0 85	14 71	0 86	0 17	8000	1370	4111
4	Jet pulse filter fan (R2P14)	30 0	7 30	0 85	35 29	2 15	0 43	8000	3443	10330
							SUB TOTAL =		**10612**	**31837**
C	**CEMENT MILL Ph # I & II**									
1	ESP screw conveyor (Z2P12)	5 5	0 60	0 85	6 47	0 37	0 07	8000	598	1795
2	Screw conveyor (Z2M11)	15 0	2 70	0 85	17 65	1 04	0 21	8000	1671	5013
3	Dedusting filter fan (Z4P23)	30 0	21 10	0 85	35 29	3 18	0 64	8000	5096	15287
							SUB TOTAL =		**7365**	**22095**
D	**PACKING PLANT Ph # I & II**									
1	Silo No 3(filter fan PH 1)	30 0	4 40	0 85	35 29	2 06	0 41	8000	3300	9901
2	Dust filter fan - P1	22 0	12 20	0 85	25 88	2 01	0 40	8000	3216	9648
3	Dust filter fan - P2	22 0	14 70	0 85	25 88	2 25	0 45	8000	3603	10808
4	Dust filter fan - P3	22 0	12 40	0 85	25 88	2 03	0 41	8000	3244	9733
5	Dust filter fan - P4	22 0	12 30	0 85	25 88	2 02	0 40	8000	3230	9691
6	Silo No 1(top filter fan PH 1)	15 0	4 00	0 85	17 65	1 09	0 22	8000	1744	5233
7	Bin aeration blower	15 0	4 30	0 85	17 65	1 10	0 22	8000	1765	5296
8	Bin aeration blower(C2U01)	15 0	4 30	0 85	17 65	1 10	0 22	8000	1765	5296
							SUB TOTAL =		**21869**	**65607**
							GRAND TOTAL =		**68793**	**262794**

APPENDIX - 6/8

L.T. MOTORS RECOMMENDED FOR AUTO DELTA-STAR CONTROLLERS

SL. No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED kW	FULL LOAD EFFIC. η	FULL LOAD POWER	OPERT. LOSSES IN kW	SAVINGS IN LOSSES kW	OPERT HOURS	ANNUAL SAVINGS kWH	COST SAVINGS Rs	INSTA--LATION COST Rs	PAY BACK PERIOD
A	PHASE # I											
1	Rubber belt Conveyor (R1A05M1)	55	21	0 85	64 71	20 8	4 2	5000	20833	62499 7	21750 0	0 35
2	Drag chain (W1K08)	30	7 1	0 85	35 29	7 1	1 4	5000	7050	21151 3	18750 0	0 89
3	ESP drag chain (J1P54M1)	11	4 2	0 85	12 94	4 2	0 8	5000	4167	12499 9	18750 0	1 50
4	ESP drag chain (J1P55M1)	11	4 1	0 85	12 94	4 1	0 8	5000	4068	12202 8	18750 0	1 54
5	ESP drag chain (J1P52M1)	11	3 9	0 85	12 94	3 9	0 8	5000	3869	11608 4	18750 0	1 62
B	PHASE # II											
1	Rubber belt Conveyor (R2L06M1)	55	9 8	0 85	64 71	9 7	1 9	5000	9740	29220 8	21750 0	0 74
2	Rubber belt Conveyor (R2A05M1)	55	19 9	0 85	64 71	19 7	3 9	5000	19744	59230 7	21750 0	0 37
3	Rubber belt Conveyor (R2A02M1)	30	6 6	0 85	35 29	6 6	1 3	5000	6555	19665 8	18750 0	0 95
4	Screw Conveyor (W2A05M1)	22	3 9	0 85	25 88	3 9	0 8	5000	3876	11628 9	18750 0	1 61
5	Screw Conveyor (W2B05M1)	30	7 5	0 85	35 29	7 4	1.5	5000	7447	22339.8	18750.0	0 84
6	Drag chain Conveyor (J2P12)	7 5	2 2	0 85	8 82	2 2	0 4	5000	2184	6550 6	18750 0	2 86
7	Drag chain Conveyor (J2P14)	7 5	2 1	0 85	8 82	2 1	0 4	5000	2084	6253 5	18750 0	3 00
C	CEMENT MILL # I & II											
1	Screw Conveyor (Z4M11)	30	3 8	0 85	35 29	3 8	0 8	5000	3782	11347 5	18750 0	1.65
2	Dedusting Filter Fan (Z4P23)	30	6 3	0 85	35 29	6 3	1 3	5000	6258	18774.5	18750 0	1 00
							TOTAL =		101658	304974.2	271500.0	0.89

REPLACEMENT OF STANDARD MOTORS BY HIGH EFFICIENCY MOTOR AND OPTIMUM SIZING

Application : Bucket Elevator P2J41 (Packing Plant)

Rated kW = 22 kW

Measured kW = 9 8 kW

Full load efficiency (Rated), η = 0 85

Derived data

Full load power $= \dfrac{\text{Rated kW}}{\text{Rated } \eta_{FL}}$

= 25 88 kW

Demand factor (D F) $= \dfrac{\text{Measured kW}}{\text{Full load power}}$

= 0.36 kW

Operating efficiency $= 1 - \dfrac{(1-\eta(k_1 + (DF)^2 \times k_2)}{DF} \times 100$

η = efficiency of motor
DF = demand factor
k_1 & k_2 are constants

Appendix - 6/9 contd..

$$= 1 - \frac{(1-0.85)\,(0.38+(0.36)^2 \times 0.62)}{0.36} \times 100$$

= 80.79 %

Operating losses	= (1-η) x measured power
	= (1 - 0.8079) x 9.3
	= 1.79 kW

It is proposed to replace this motor by a high efficiency motor having a rated capacity of 11 kW

Rated full load efficiency	= 92%
Operating efficiency of the motor with the present loading (using the same formulae)	= 91.54%
Operating losses	= (1 - 0.9154) x 9.3
	= 0.79 kW
Reduction in losses	= 1.79 - 0.79
	= 1.00 kW
Operating hours	= 8000/annum
Annual energy savings	= 7994 kWh

Appendix - 6/9 contd..

Annual cost savings	= Rs.23983/- @ Rs.3.00/kWh
Cost of implementation	= Rs.18,040/-
Simple payback period	= 0.75 years

Similar calculation for sizing of motors through computation has been carried out. Appendix - 6/9 represents the techno-economics for replacement of ordinary motors by high efficiency motors and sizing

Appendix - 6/9 contd..

OPTIMUM SIZING AND USE OF ENERGY EFFICIENT MOTORS

SL. No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED kW	FULL LOAD EFFICIENCY (η)	PROPOSED HIGH EFFICIENCY MOTOR (kW)	ANNUAL OPERATING HOURS	ANNUAL SAVINGS IN kWh	ANNUAL COST SAVINGS Rs	INSTALATION COST IN Rs.	PAY BACK PERIOD IN YEARS
A	**PHASE # I**									
1	RBC (R1A04M1)	30 0	12 3	0 85	22 0	8000	10957	32872	33066	1 01
2	RBC (R1A03M1)	30 0	15 0	0 85	22 0	8000	10685	32055	33066	1 03
3	Dust filter fan (H1P04M1)	15 0	7 2	0 85	11 0	8000	5011	15033	18040	1 20
4	Bucket elevator (W1J03M1)	90 0	45 6	0 88	90 0	8000	25483	76450	138512	1 81
5	Blower for old bin (H1H09)	22 0	9 9	0 85	15 0	8000	8269	24808	22451	0 91
6	DBC (U2J03)	55 0	28 8	0 88	45 0	8000	16811	50432	72897	1 45
7	Fan for air seal (W1K30)	45 0	22 2	0 85	37 0	8000	18300	54900	58652	1 07
8	Filter fan (K1P63)	15 0	6 6	0 85	11 0	8000	4968	14903	18040	1 21
9	FK Pump Blower (W1U43)	160 0	73 8	0 88	110 0	8000	52275	156825	171149	1 09
10	Dust filter fan (U1P14M1)	45 0	24 6	0 85	37 0	8000	18496	55487	58652	1 06
11	Bucket elevator (R1J13M1)	110 0	76 5	0 88	110 0	8000	41030	123090	171149	1 39
12	filter fan Silo Top (H1P14M1)	55 0	35 7	0 88	45 0	8000	17116	51347	72897	1 42
B	**PHASE # II**									
1	Bucket elevator (R2J02M1)	110 0	90 0	0 88	110 0	8000	45433	136299	171149	1 26
2	RBC (R2A06M1)	30 0	9 2	0 85	22 0	8000	10658	31975	33066	1 03
3	Pneumatic Screw pump(W2U01)	45 0	13 5	0 85	30 0	8000	17876	53629	46860	0 87
4	Pneumatic Screw pump(W2U03)	37 0	6 8	0 85	30 0	8000	13278	39833	46860	1 18
5	Pneumatic conveyor (K2U05)	75 0	18 6	0 88	55 0	8000	21075	63225	93357	1.48
6	Bucket elevator (R2J13M1)	110 0	82 5	0 88	110 0	8000	43557	130670	171149	1 31
7	Primary Air Fan (W2V07)	90 0	58 1	0 88	75 0	8000	29810	89431	119427	1 34
8	Water Pump 1 (R2X50)	30 0	23 1	0 85	30 0	8000	15885	47655	46860	0.98
9	Water Pump 1 (R2X52)	30 0	30 1	0 85	30 0	8000	15158	45475	46860	1 03
C	**CEMENT MILL Ph # 1 & 2**									
1	Screw conveyor(Z1M11)	15 0	2 6	0 85	11 0	8000	4775	14325	18040	1 26
2	Screw conveyor(Z3M11)	15.0	2 7	0 85	11 0	8000	4778	14334	18040	1 26

Appendix - 6/9 contd..

OPTIMUM SIZING AND USE OF ENERGY EFFICIENT MOTORS

Sht 2 of 2

SL No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED kW	FULL LOAD EFFICIENCY (η)	PROPOSED HIGH EFFICIENCY MOTOR (kW)	ANNUAL OPERATING HOURS	ANNUAL SAVINGS IN kWh	COST SAVINGS IN Rs	INSTALATION COST IN Rs.	PAY BACK PERIOD IN YEARS
D	PACKING PLANT - PH # I & II									
1	Bucket elevator (P2J31)	22.0	13.1	0.85	22.0	8000	8072	24216	33066	1.37
2	Jet Pulse filter fan (P2P23)	22.0	13.8	0.85	22.0	8000	8301	24903	33066	1.33
3	Compressor (P2X11)	132.0	88.5	0.88	132.0	6000	36365	109095	214687	1.97
4	Screw conveyor(P2J02)	11.0	3.0	0.85	11.0	8000	2779	8337	18040	2.16
5	Screw conveyor(P2J03)	22.0	9.4	0.85	11.0	8000	8198	24595	18040	0.73
6	Compressor (P2X14)	45.0	28.2	0.85	45.0	6000	14485	43456	72897	1.68
7	Bucket elevator (P2J21)	22.0	2.7	0.85	22.0	8000	6075	18226	33066	1.81
8	Screw conveyor(P2J05)	11.0	1.2	0.85	11.0	8000	2624	7871	18040	2.29
9	Bucket elevator (P2J41)	22.0	9.3	0.85	11.0	8000	7994	23983	18040	0.75
10	Bucket elevator (P2J51)	22.0	1.5	0.85	11.0	8000	8885	26654	18040	0.68
11	Bucket elevator (P2J61)	22.0	10.5	0.85	11.0	8000	7823	23469	18040	0.77
12	Screw conveyor(P2J06)	11.0	2.5	0.85	11.0	8000	2722	8167	18040	2.21
13	Screw conveyor(P2J04)	22.0	5.7	0.85	11.0	8000	8750	26251	18040	0.69
14	Main RBC (P2U62)	11.0	1.4	0.85	7.5	8000	3653	10958	18612	1.70
15	Bottom RBC (P2U56)	11.0	1.2	0.85	7.5	8000	3651	10953	18612	1.70
16	Top RBC (P2U55)	15.0	2.8	0.85	11.0	8000	4781	14342	18040	1.26
17	Rly side bottom RBC (P2U44)	18.5	4.2	0.85	15.0	8000	5540	16620	22451	1.35
18	Rly side bottom RBC (P2U54)	18.5	4.5	0.85	15.0	8000	5559	16676	22451	1.35
19	Rly side top RBC (P2U43)	15.0	2.4	0.85	11.0	8000	4770	14310	18040	1.26
20	Rly side top RBC (P2U53)	15.0	3.0	0.85	11.0	8000	4787	14361	18040	1.26
21	Compressor (P2X16)	110.0	83.7	0.88	110.0	4000	22070	66209	171149	2.58
22	Bucket elevator (P1J11)	22.0	3.6	0.85	22.0	8000	6144	18433	33066	1.79
23	Bucket elevator - P2	22.0	2.2	0.85	22.0	8000	6046	18137	33066	1.82
24	Screw conveyor - P2	22.0	7.9	0.85	15.0	8000	8112	24337	22451	0.92
25	Screw conveyor - P3	22.0	10.1	0.85	15.0	8000	7535	22606	22451	0.99
26	Bucket elevator - P4	22.0	1.5	0.85	22.0	8000	6014	18042	33066	1.83
						Total =	663420	1990260	2662836	

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APPENDIX - 6/10

INSTALLATION OF SOFT STARTER FOR VARIABLE LOADED MOTORS

Area : Scraper # 1

Application : **Harrow Hydraulic Pump (A1L04M6)**

Rating = 37 kW

Soft starter senses the motor load and accordingly controls the magnitude of input voltage to motor terminal in order to improve efficiency and reduce the losses.

The observations recorded along with the calculations are given below:

No load operation cycle = 1650 hrs/annum

Measured power = 10.3 kW

Average PF = 0.46

Operating voltage = 410

θ $= \cos^{-1} (0.46)$

$= 62.61^{0}$

V_{motor} $= (\sqrt{2}\ V_{op}) \sqrt{\tfrac{1}{2\pi} \{\theta-(\sin 2\theta/2)\}^{\pi}_{62}}$

= 362 V

% reduction in voltage = 12%

Appendix - 6/10 contd..

% reduction in losses	$= [1 - (1 - 0.12)^2]$
	= 21.83%
Operating losses (assuming 80% η for motor)	= 0.2 x 10.3 kW
	= 2.06 kW
Savings in losses in kW	= 2.06 x 0.2183
	= 0.45 kW
Annual energy savings	= 0.45 x 1650 (@ 5hrs/day for 330 days/year)
	= 742 kWh
Annual cost savings	= Rs.2226/- @ 3.00/kWh
Load operation cycle	= Rs.5610 hours/annum
Measured power	= 25.5 kW
Power factor	= 0.73
Operating voltage	= 410 V
θ	$= \cos^{-1} (0.73)$
	$= 43.11^0$
V_{motor}	$= (\sqrt{2}\, V_{op}) \sqrt{\tfrac{1}{2}\pi \{\theta - (\sin 2\theta/2)\}^{\pi}_{43}}$
	= 393 V
% reduction in voltage	= 4%

Appendix - 6/10 contd..

% reduction in losses	$= [1 - (1 - 0.04)^2]$
	= 8 12%
Operating losses (assuming 80% η for motor)	= 0.2 x 25.5
	= 5.10 kW
Savings in losses in kW	= 5.10 x 0.0812
	= 0.41 kW
Annual energy savings	= 0.41 x 5665 (@ 17hrs/day for 330 days/year)
	= 2323 kWh
Annual cost savings	= Rs.6969/- @ Rs.3.00/kWh
Total annual energy savings	= 742 + 2323 kWh
	= 3065 kWh
Total annual cost savings (X)	= Rs.2226/- + Rs.6969/-
	= Rs.9195/-
Cost of installation (A)	= Rs.44980/-
Capacitor released	= 15 kVAr
Cost of Capacitor bank released (B)	= Rs. 4500/- (@ Rs.300/- per kVAr)

Appendix - 6/10 contd..

Release of kVA demand	= 20 kVA
Considering 50% of kVA demand savings per annum,	
Annual Cost of demand saving (Y)	= Rs.18000/- (@ Rs.150/- per kVA)
Net Annual cost of energy savings (X +Y)	= Rs.27195/-
Actual Cost of implementation (A - B)	= Rs.40480/-
Simple Payback period	= 1.48 years

Similar calculation for installation of energy savers for various motors has been carried out and is represented in Appendix - 6/10a and 6/10b.

ENERGY SAVINGS BY USE OF ELECTRONIC ENERGY SAVERS

Sl. No.	APPLICATION / CONNECTED EQUIPMENT	RATED kW	VOLT -AGE	Pf Cos ϕ	SCR FIRING ANGLE	kW DRAWN	OPER- -TING Hrs/ DAY	MOTOR TERMI- -NAL VOLT	REDUC- -TION IN VOLT. %	REDUC- -TION IN LOSSES %	OPERAT- -ING AT 80% η IN kW	SAVING IN LOSSES IN kW
1	Harrow Hyd Pump (A1L04M6) uL	37 0	410	0 46	63	10 3	5	362	12	21.83	2 06	0.45
	- do - L	37.0	410	0.73	43	25.5	17	393	4	8 12	5.10	0.41
2	Hammer mill (W1M01)	150.0	423	0 29	73	11 4	24	349	17	31 85	2 28	0.73
3	Hammer mill (W2M01)	190 0	428	0 45	63	15 6	24	377	12	22 40	3.12	0.70
4	Harrow Hyd. Pump (A2L04M7)	37 0	414	0 55	57	15.9	22	377	9	16 89	3 18	0.54
5	Atox mill Hyd. system	7 5	438	0 32	71	4 4	20	366	16	30.03	0 88	0 26
6	Drag chain conveyor (W2K50)	7 5	431	0 53	58	3 2	24	390	9	17.96	0 64	0 11
7	Rly side bottom RBC (P2U44)	18 5	421	0 53	58	4.2	24	381	9	17.96	0 84	0.15
8	Rly side bottom RBC (P2U54)	18 5	416	0.53	58	5 2	24	377	9	17.96	1.04	0.19
9	Compressor (P2X16) L	110 0	423	0 71	45	83 7	8 5	404	5	9 00	16 74	1 51
	- do - uL	110 0	424	0 37	68	23 1	6 5	362	15	27.04	4 62	1 25

NOTE . Techno-economics of energy savings is represented in Appendix - 6/10 b

TATA ENERGY RESEARCH INSTITUTE
BANGALORE

APPENDIX - 6/10b

TECHNO-ECONOMICS OF ENERGY SAVINGS BY USE OF ELECTRONIC ENERGY SAVERS

Sl. No.	APPLICATION / CONNECTED EQUIPMENT	RATED kW	Pf Cos ϕ	kW MEA-SUR-ED	REDUC-TION IN VOLT %	ANNUAL SAVINGS IN kWh	ANNUAL ENERGY SAVINGS IN Rs (X)	INSTAL-ATION COST IN Rs (A)	MONTHLY SAVINGS IN kVA	ANNUAL DEMAND SAVINGS IN Rs (Y)	CAP. RELEASED IN kVAr	COST OF RELEASED CAP. IN Rs (B)	IMPLEMEN-TATION COST IN Rs (A - B)	NET ANNUAL COST SAVINGS IN Rs (X + Y)	SIMPLE PAY BACK PERIOD IN YEARS
1	Harrow Hyd Pump (A1L04M6) uL	37.0	0.46	10.3	12	742	2226	44980	20	18000	15	4500	40480	27195	1.5
	- do - L	37.0	0.73	25.5	4	2323	6969								
2	Hammer mill (W1M01)	150.0	0.29	11.4	17	5751	17253	109900	52	46800	30	9000	100900	64053	1.6
3	Hammer mill (W2M01)	190.0	0.45	15.6	12	5535	16605	144900	60	54000	30	9000	135900	70605	1.9
4	Harrow Hyd Pump (A2L04M7)	37.0	0.55	15.9	9	3899	11698	44980	18	16200	15	4500	40480	27898	1.5
5	Atox mill Hyd system	7.5	0.32	4.4	16	1744	5232	24980	3	2700	3	900	24080	7932	3.0
6	Drag chain conveyor (W2K50)	7.5	0.53	3.2	9	910	2731	24980	3	2700	3	900	24080	5431	4.4
7	Rly side bottom RBC (P2U44)	18.5	0.53	4.2	9	1195	3585	28980	7	6300	6	1800	27180	9885	2.7
8	Rly side bottom RBC (P2U54)	18.5	0.53	5.2	9	1479	4438	28980	7	6300	6	1800	27180	10738	2.5
9	Compressor (P2X16) L	110.0	0.71	83.7	5	4227	12682	97900	40	36000	50	15000	82900	56721	1.5
	- do - uL	110.0	0.37	23.1	15	2680	8040	550580	210	189000	158	47400	503180	280459	
					TOTAL =	30486	91459	550580	210	189000	158	47400	503180	280459	1.8

DESIGN PARAMETERS OF REFRIGERATION MACHINES & CHILLER PUMPS

A. Refrigeration Machines

Sl No	Location	Make & Type of units	No of Units	Rated TR	Compressor			Chilled Water				Condenser Water				Annual Operating Hours
					Rated Power,kW	Suction Pre , psi	Delivery Pre , psi	Temp , °C		Pre ,kg/cm²(g)		Temp , °C		Pre ,kg/cm²(g)		
								inlet	Outlet	inlet	Outlet	inlet	Outlet	inlet	Outlet	
1	CCR-Bldg	VOLTAS-Chilled Water System	2	40x2	45 each	60	250	12 8	7 2	3 2	2 5	35	41	3 0	2 5	7920
2	CCR-Bldg	VOLTAS-Chilled Water System	1	40	37	60	250	12 8	7 2	3 2	2 5	35	41	3 0	2 5	4400
3	CCR-Bldg	VOLTAS-Chilled Water System	1	40	45	60	250	12 8	7 2	3 2	2 5	35	41	3 0	2 5	2500
4	ADM-Bldg	VOLTAS-Chilled Water System	1	40	45	60	250	12 8	7 2	3 2	2 5	35	41	3 0	2 5	2300
5	ADM-Bldg	VOLTAS-Chilled Water System	2	20x2	45 each	60	250	12 8	7 2	3 2	2 5	35	41	3 0	2 5	2000

Appendix - 7/1 contd..

B. Chiller Pumps

Sl No	Usage Area	Make	No Installed	No Operated	Rated Power, kW	Designed Range		Annual Operating hours
						Flow, lps	Head, m	
	CCR - PLANT ROOM							
1.	M/C No 1	BEACON	2	1 (1 Standby)	2 2 each	5 0 - 11 5	22 5 - 11.0	2500
2.	M/C No. 2, 3 & 4	BEACON	2	1 (1 Standby)	7 5 each	N A	N A	7920
	ADM - PLANTROOM							
1.	M/C No 1, 2 & 3	BEACON	3	2 (1 Standby)	2 2 each	2 7 - 7 5	33 2 - 13.7	2300

MACHINE SIDE OBSERVATIONS ON REFRIGERATION MACHINES

Sl. No	System	Compressor				Chilled Water in Chiller				Cooling Water in Condenser				Chilled Water Pump	Measured Power, kW		Remarks
		Pressure psi		Temperature°C		Pressure kg/cm^2(g)		Temperature °C		Pressure kg/cm^2(g)		Temperature °C			Compressor	Chilled Water Pump	
		Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Head, m			
CCR - PLANT ROOM																	
1	M/C - 1	43	194	0	40	2 2	1 2	8 5	5	2 5	1 7	22	25 0	12	28 9	2 34	Compressor loaded to 75%
2	M/C - 2	48	186	2	39	3 2	2 7	17 0	12	2 2	1 7	23	26 5	23	30 9	6 50	Compressor loaded to 75%
3	M/C - 3	Under Maintenance															
4	M/C - 4	53	206	4	42	3 2	2 7	17 0	12	2 2	1.7	23	26 5	-	21 3	-	Compressor loaded to 100%
ADM - PLANT ROOM																	
5	M/C - 1	51	168	3	35	2 3	2 0	11 5	10	1 2	0 2	21 5	24 0	19	29 6	6 82	Compressor loaded to 100%
6	M/C - 2	Under Maintenance															
7	M/C - 3	Under Maintenance															

APPENDIX - 7/3

CALCULATION OF GENERATION TONS OF REFRIGERATION (GEN-TR)

CCR BUILDING PLANTROOM

A. Machine No. 1

i.	Chilled water pump power input	= 2.34
ii.	Pressure on the discharge side	$= 2.2\ kg/cm^2$
iii.	Pressure on the suction side	$=1.0\ kg/cm^2$
iv.	Total pressure head on the pump	$= 1.2\ kg/cm^2$
v	Efficiency of Pump-Motor Unit	= 43%
vi.	Average chilled water flow (Q_f)	$= \dfrac{P X\ \eta_{(P-M)}\ X\ 3600}{9.81\ X\ H}$
		$= \dfrac{2\ 34\ X\ 0.43\ X\ 3600}{9\ 81\ X\ 12}$
		$= 30.77\ m^3/h$
vii	Temperature drop across chiller	$= 3.5^0C$
viii.	Tons of refrigeration	$= \dfrac{Q_f\ x\ 1000\ x\ \Delta T}{3024}$
		= 35.61 TR

Appendix - 7/3 contd..

ix. Rated capacity = 40 TR

x. % TR generation (3 Cylin. in operation) $= \dfrac{35.61}{40} \times 100$

$= 89.0\ \%$

B. Machine No. 2 & 3

i. Chilled water pump power input = 6.5

ii. Pressure on the discharge side $= 3.3\ kg/cm^2$

iii. pressure on the suction side $=1.0\ kg/cm^2$

iv. Total pressure head on the pump $= 2.3\ kg/cm^2$

v. Efficiency of Pump-Motor Unit = 43%

vi Average chilled water flow (Q_f) $= \dfrac{P X \eta_{(P-M)} X 3600}{9.81 X H}$

$= \dfrac{6.5 \times 0\ 43 \times 3600}{9.81 \times 23}$

$= 44.60\ m^3/h$

vii. Temperature drop across chiller $= 5.0^0C$

viii. Tons of refrigeration $= \dfrac{Q_f \times 1000 \times \Delta T}{3024}$

$= 73.74$ TR

ix. Rated capacity $= 2 \times 40 = 80$ TR

x. % TR generation (3 Cylin. in operation for M/c.2 & 4 Cylin in operation for M/c.3) $= \dfrac{73.74}{80} \times 100$

$= 92.2\ \%$

: DM BUILDING PLANTROOM

A. Machine No. 1

i. Chilled water pump power input = 6.1

ii Pressure on the discharge side = 2.3 kg/cm^2

iii. Pressure on the suction side =0.5 kg/cm^2

iv. Total pressure head on the pump = 1.8 kg/cm^2

v. Efficiency of Pump-Motor Unit = 43%

vi. Average chilled water flow (Q_f)

$$= \frac{P \times \eta_{(P-M)} \times 3600}{9.81 \times H}$$

$$= \frac{6.1 \times 0.43 \times 3600}{9.81 \times 18}$$

= 53.48 m^3/h

vii. Temperature drop across chiller = 1.5^{0}C

viii. Tons of refrigeration

$$= \frac{Q_f \times 1000 \times \Delta T}{3024}$$

= 26.5 TR

ix. Rated capacity = 40 TR

x. % TR generation

$$= \frac{26.5}{40} \times 100$$

= 66.3 %

EVAPORATOR & CONDENSER EFFECTIVENESS

Sl No	Particulars	Evaporator							Condenser						
		Pressure, kg/cm^2(g)			Temperature°C			Remarks	Pressure, kg/cm^2(g)			temperature			Remarks
		Inlet	Outlet	Pre.drop	Inlet	Outlet	Temp drop		Inlet	Outlet	Pre drop	Inlet	Outlet	Temp rise	
CCR - PLANT ROOM															
1	M/C - 1	2 2	1 2	1.0	8 5	5	3 5	Pre drop high	2 5	1 7	0 5	22	25	3 0	Acceptable Pre.drop
2	M/C - 2	3 2	2.7	0 5	17	12	5 0	Acceptable Pre drop	2 2	1 7	0 5	23	26 5	3 5	Acceptable Pre.drop
3	M/C - 4	3 2	2.7	0 5	17	12	5 0	Acceptable Pre drop	2 2	1.7	0 5	23	26 5	3.5	Acceptable Pre.drop
ADM - PLANT ROOM															
4	M/C - 1	2 3	2 0	0 3	11 5	10	1.5	Acceptable Pre drop	1 2	0 2	1.0	21.5	24	2.5	Pre.drop high

AHU -TONS OF REFRIGERATION (AHU-TR)

1. MEASURED CONDITIONS

Sl No	Location	AHU Model	Rated Air Flow	Average Air Velocity	Area of Filter	Actual Air Flow	Air Temperature Before Filter		Air Temperature After Cooling Coils	
			cfm	m/s	m^2	cfm	DBT ^{0}C	WBT ^{0}C	DBT ^{0}C	WBT ^{0}C
CCR Bldg - Plant										
1	I - Flr	AHU - 11	22500	2 62	2 93	16225	22	14 5	10 5	9.7
2	II - Flr, CCR	AHU - 7	7500	1 35	2 48	7232	23 5	15.5	18 5	13.5
3	II - Flr, PLC	AHU - 7	7500	1 40	2 48	7350	23	14	17	11.5
4	Ground Flr, PLC	AHU - 11	22500	0 83	6 18	10860	28	19	26	18
ADM Bldg - Plant										
5	Ground Flr, Personal	AHU - 7	7500	1 05	2 48	5268	21 5	15 5	14	12.5
6	Ground Flr, Conference Hall	AHU - 7	7500	1 02	2.48	5176	23	16.5	15 5	13
7	I - Flr, Purchase	AHU - 7	7500	1 21	2.48	6130*	22 5	16.3	17.5	13
8	I - Flr, Accounts	AHU - 7	7500	1 22	2.48	6142	22 5	15.5	16.5	13

Openings have been observed between filter mats.

2.0 USER LOAD ASSESSMENT

Sl No	Location	Actual Air Flow	Specific volume of Air before filter	Ave.Specific moisture in air before filter	Ave Specific moisture in air before filter	Sensible Heat load* on AHU	Latent Heat load** on AHU	Total Refrig. load on AHU
		m^3/h	m^3/kg	kg/kg of dry air	kg/kg of dry air	TR	TR	TR
CCR	**Bldg - Plant**							
1	I - Flr	27590	0.846	0 0074	0 0073	29 77	0 58	30.35
2	II - Flr, CCR	12053	0.852	0 0077	0 0075	5 61	0 51	6.12
3	II - Flr, PLC	12500	0 847	0 0063	0 0062	7 03	0 26	7.29
4	Ground Flr, PLC	18465	0 866	0 0100	0 0095	3 38	1.90	5 29
ADM	**Bldg - Plant**							
5	Ground Flr, Personal	8958	0 846	0 0085	0 0085	6 30	0 00	6.30
6	Ground Flr, Conference Hall	8800	0.852	0.0092	0 0083	6.15	0 92	7.07
7	I - Flr, Purchase	10421	0 849	0 0090	0 0075	4 87	2 19	7.06
8	I - Flr, Accounts	10443	0 848	0 0081	0 0079	5 86	0 44	6.30

* (Air flow rate/Sp vol of air before filter) x D B T Diff across chiller x 0 24/3024

** (Air flow rate/Sp. vol of air before filter) x Sp moisture Difference across chiller x 540/3000

APPENDIX - 7/6

INSTALLATION OF ADDITIONAL SOLAR FLAT PLATE COLLECTORS

The canteen building has enough space to install atleast 16 more solar flat plate collectors By connecting them in parallel with the existing system more hot water could be generated.

Max possible water outlet temperature (summer)	= 95 ° C
Min.possible water outlet temperature (winter)	= 45 ° C
Ave Water outlet temperature	= 60° C
No of collectors required to supply 1000 lpd	= 8
Amount of hot water generation possible	= 2000 lpd
Water requirement of canteen	= 40 m^3/day
	= 40,000 lpd
Percentage of hot water utilisation	= 40% of total water supplied
Hot water requirement of canteen	= 16000 lpd
Heat gained by solar water heater	= Mass flow rate of water x sp heat x temp rise of water
	= 2000 x 1 x (60 - 30)
	= 60000 kcal/day

Appendix - 7/6 contd..

Assuming LPG (calorific value - 10800 kcal/kg) as the fuel used

Equivalent fuel savings	$= \dfrac{60000}{10800}$
	= 5.5 kg/day
Annual days of operation	= 300
Annual fuel savings	= 1650 kg of LPG
Annual energy savings	= 180 lakh kcal

Taking the LPG cost to be Rs.24 / kg,

Annual cost savings	= 1650 x 24
	= Rs 39600/-
Investment cost	= Rs 2.4 lakhs
Simple payback period	$= \dfrac{240000}{39600}$
	= 6 06 years

APPENDIX - 8/1

DETAILS OF LIGHTING FIXTURES

L & T ACW PHASE - I

Sl No	Area/ Location	Fluorescent Fixture 1 X 40W	Fluorescent Fixture 2 X 40W	HPSV 70W	HPSV 250W	Focus Lamps 400W	Remarks
1	Coal Mill Area	12	93	139	41	* 3	*Incandescent lamp 500W
2	Raw Mill Area	-	98	53	32	2	-
3	Preheater Area	9	185	88	55	9	-
4	Kiln Area	4	6	4	-	* 1	*Incandescent lamp 500W
5	Cement Mill Area	16	165	29	35	3	-
6	Clinker and Gypsum yard + Miscellaneous	06	236	172	-	36	-
	Total	47	783	485	163	54	

Note 1 In absence of any structured data, an effort has been made to collect above information for Phase - I (only mill areas), which is towards lower side

2 For Phase -II, similar number of fixture is considered for any calculation purpose

L & T ACW MINES

Sl No	Area/ Location	Fluoroscent Fixture	Fluorescent Fixture	HPSV	Flood Light	
		1 X 40W	2 X 40W	70 W	1 X 400W	2 X 400W
1	Quarry Mines	-	-	-	31	19
2	Street Light	-	-	71	-	-
3	Garage	-	-	25	5	-
4	Office/ S/S & other spaces	138	-	-	-	-
5	LSC II and Conveyor B	-	-	70	-	-
	Total	138	-	166	36	19

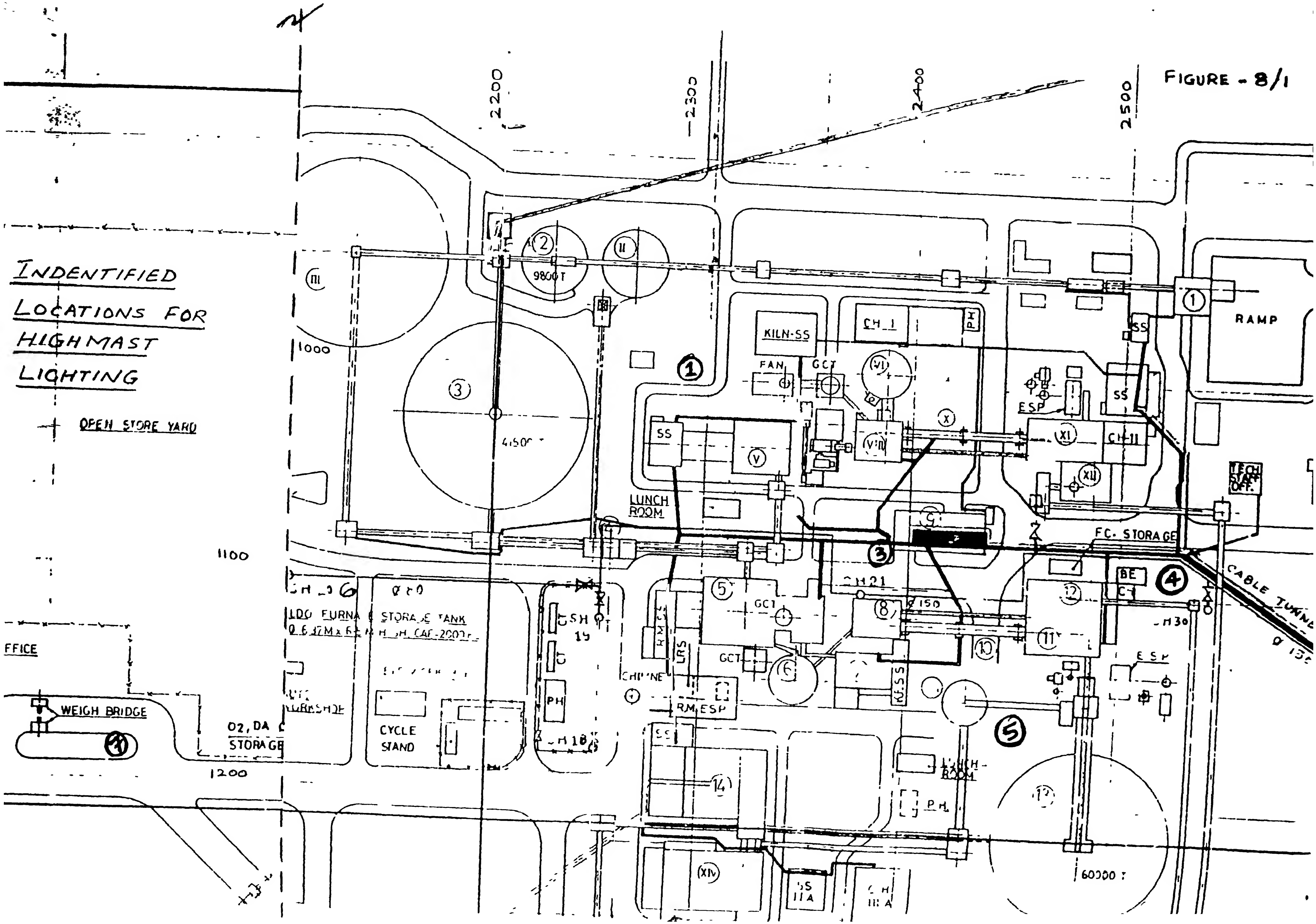

INDENTIFIED LOCATIONS FOR HIGHMAST LIGHTING
OPEN STORE YARD
2200
2300
2400
2500
1000
1100
1200
RAMP
SS
KILN-SS
CH 1
PH
FAN
GCT
ESP
CH-11
LUNCH ROOM
F.C. STORAGE
CABLE TUNNEL
BE
CH21
RMS
LRS
CHIMNEY
RM.ESP
CH 19
CT
PH
CH 18
LDO FURNACE STORAGE TANK
CYCLE STAND
O2, DA STORAGE
WEIGH BRIDGE
FFICE
SS IIA
CH IIA
PH
LUNCH ROOM
9800 T
4500 T
60000 T

FIGURE - 8/1

APPENDIX - 8/2

ANALYSIS OF FLUORESCENT FIXTURES IN SUBSTATIONS

Sl No	Substation	Single T/L fixture	Double T/L fixture	Total no of tubes	Tubes not working	No of tubes glowing pink	Remark
1	M S S	-	38	76	4	-	Mainly 'OFF' during day
	PHASE - I						
2	HPC-1	3	37	77	6	1	Mostly 'ON'
3	HPC-2	18	52	122	10	3	Mostly 'ON'
4	HPC-2A	11	50	111	7	6	Mostly 'ON'
5	PUMP HOUSE (MCC + PUMP ROOM)	-	14	28	2	1	Luminaires require cleaning
6	OLD MINES S/S	-	14	28	6	-	Occasionally kept 'ON'
7	HPC-3	2	31	64	2	1	Mostly 'ON'
8	HPC-4	6	10	26	3	-	Mostly 'ON'
	PHASE - II						
9	S S-1	12	42	96	20	2	Mostly 'ON'
10	S S-2 & 2A	60	10	80	6	2	Mostly 'ON'
11	S S -SB	35	48	131	11	1	Mostly 'ON'
12	S S-3	44	29	102	18	2	Includes PCC-3A S/S
13	PACKING PLANT S/S	-	10	20	3	1	Tubes are at 6/7M height HPMV and HPSV also used
	TOTAL			961	98(10%)	20(2%)	

* Power wastage per day → 33 kWh (with 0.8 diversity factor)
* Average power wastage per annum → 10,890 kWh p a
  = Rs.32,670/- p.a

APPENDIX - 8/3

DETAILS OF AREA LIGHTING

PHASE - I

Date : 23.12.96

Sl No	Area	400W	250W	70W	300W
1	New Coal Mill Building CCR side	-	2	-	-
2	Coal Mill Esp. area	-	1	-	-
3	Coal Mill Hopper Top area	2	-	-	-
4	J2J08 Clinker Conveyor	-	8	-	-
5	W2J05 Clinker Conveyor & W1J06 Clinker Conveyor	-	-	-	2
6	Ph-I Preheater area Light	3	-	-	-
7	PH-I Comp house area light K/F	-	-	-	1
8	Chimney area light	1	-	-	-
9	Pump house area light	-	-	10	-
10	RIA04 & R2A04 T H area light	1	2	-	-
11	Iron Ore yard PH-I	-	1	-	-
12	PH -I L. S. Crusher H.P C4	-	2	-	-
13	M S S Meter Room area top	-	2	-	-
14	M S Switch yard	-	9	-	-
15	M.S S Building top	-	3	-	-
16	D G.set building area light	-	5	-	-
17	PH-I Coal crusher building area light	-	4	-	1
18	T House Coal Crusher	-	-	-	1
19	Coal yard Tower light	-	5	-	-
20	Coal yard tower near Gypsum yard	-	5	-	-
	Sub-Total Wattage	2800	12250	700	1500

Total Wattage = 17250 W

Appendix - 8/3 contd..

PHASE - II

Sl No	Area	400W	250W	70W	300W
1	PH-II Coal Mill area light	-	1	-	-
2	Coal Mill Esp area light	-	2	-	-
3	K/F comp. room top area light	-	2		
4	C F Silo area light	-	1	-	-
5	J2P09 Motor Shed	-	1	-	-
6	Raw Mill PH-II area light	4	-	-	-
7	R2A02 T H area light	-	2	-	-
8	Cement Mill comp H PH-II area light	2	-	-	-
9	Cement Mill 1 & 2 area light	-	1	-	-
10	Cement Mill 3 & 4 area light	-	2	-	-
11	New Coal Crusher area light	-	3	-	
12	L1U11 Coal Belt & End side	1	-	-	-
13	T.House L1U11 & U12 RBC	-	2	-	-
14	Rly. yard near Rly office Tower Pole (1 & 2nd step)	-	10	-	-
15	Coal Crusher Near Tower Pole (1 & 2nd step)	-	10	-	-
16	PH-I Rly shed area light	-	9	-	-
17	PH-II Rly. shed area light	-	1	-	-
18	PH-II Rly. yard near Tower area light (1 & 2nd step)	-	10	-	-
19	Loco shed near Tower (1 & 2nd step)	-	10	-	-
20	PH-II P P Silo No.10 area light	03	-	-	-
21	PH-I luffing Belt area light	-	01	-	-
22	PH-II truck side Bottom Belt yard area light	-	8	-	-
23	Gypsum Hopper area light	-	01	-	-
	Sub-Total Wattage	4000	9520	-	-

Total Wattage = 13520 W

APPENDIX - 8/4

A.C.W COLONY STREET LIGHT DETAILS

Sl. No	Area / Location	70W HPSV Road Light 12M ht	70W HPSV Road Light 10M ht	MV 125W Ground Light 8M ht.	Halogen Fittings 250W	Flood Light 400W
1	Main Gate to 'G' type Bus Stop	28	-	-	-	-
2	Main Gate to Nanda Fata gate	45	-	-	-	-
3	Colony Gate to A C W canteen (Nanda Fata)	37	-	-	-	-
4	'F' type to mines gate	28	-	-	-	-
5	Lagoon guest house to staff colony (near ADM)	27	-	-	-	-
6	'F' type & play ground	05	11	5	-	-
7	'E' type colony Ground & Road	-	3	21	-	-
8	Badminton Ground	-	-	-	6	-
9	'A' type colony club area	-	7	-	6	6
10	'A', 'B', & 'C' type colony	-	31	-	-	-
11	Muktangan Play Ground	-	-	8	-	-
12	'E' type road near mine side	-	07	-	-	-
13	Gomati Marg to Hospital	23	4	-	-	-
14	'G' type back side	-	-	11	-	-
15	Old 'G' type road light	-	24	-	-	-
16	'H' type ground light	-	-	15	-	-
17	'H' type to new 'G' type road	16	-	-	-	-
18	New 'G' type ground light 1 New 'G' type ground light 2	-	-	29 21	-	-
19	Street light new 'G' type	8	-	-	-	-
20	ADM Building area	-	-	4	-	-
21	Nursery Road	1	-	-	-	-
	Total	218	87	114	12	6
	Total Wattage	15260	6090	14250	3000	2400

Grand Total = 41000 W

APPENDIX - 8/5

LIGHTING LOAD MEASUREMENTS

PLANT : Phase # I & # II

Date :20 / 12 / 96
Time : 20 00 Hrs

Sl No	L.D.B.Details	Ph	Measured					Remarks
			Volt	Amp	Cosφ	kVA	kW	
1	MLDB -	R	243	230	0 75	63 00	44 30	Raw Mill
	HPC-1	Y	243	215	0 73	52 80	35 40	PCC-Ph-I
	Raw Mill	B	-243	153	0.72	43 40	25.00	I_N = 93 0A
2	MLDB -II	R	238	249	0 82	59 20	47 00	Includes the load
	HPC-2	Y	241	193	0 79	46 60	36 90	of CCR A/C plant
	(Shutter End)	B	241	169	0 77	40.10	33 50	(31 50 kW) I_N = 60 A
3	MLDB	R	246	54 80	0.63	13 50	7 10	I_N = 46.5 A
	S S - I	Y	243	107 00	0 74	26 20	17.60	
		B	246	61 50	0 86	15 28	11.14	
4	MLDB	R	237	87 3	0 70	20.70	12.63	Energy Saver
	HPC - 3	Y	216	32.5	0 69	7 03	4 22	3X25kVA connected
		B	217	70.5	0 70	15 35	8 79	I_N = 40.6 A
5	MLDB	R	236	108.10	0.67	26.80	15.94	Energy Saver
	S.S - 3	Y	246	118.00	0.72	29 70	18.30	in use
	(Cement Mill & CGPS)	B	249	91.00	0.74	22.60	14 75	I_N = 0
6	MLDB	R	220	19.30	0 83	4.38	3.20	
	L/S crusher	Y	224	10 80	0.67	2.45	1.45	I_N = 17.6 A
	(Belts + Crusher)	B	224	25.30	0.74	5.70	3.50	

Appendix - 8/5 contd..

Sl No	L.D B.Details	Ph	Measured					Remarks
			Volt	Amp	Cosϕ	kVA	kW	
7	MLDB	R	239	37.00	0 68	8.80	5.70	
	HPC-2	Y	241	26.20	0.34	6 34	1 36	I_N = 14 1A
	(PCC-Module IF-2F-3F)	B	241	40.30	0.69	9.68	6 20	
8	MLDB	R	248	199 00	0.75	50 00	33 00	
	Packing Plant	Y	248	167 00	0 77	41 00	27 60	I_N = 79 7A
		B	249	129 50	0.81	32 80	22 10	
9	M.L.Feeder	R	245	61 80	0 73	15 00	9.00	
	(PCC 8/13 of P/P)	Y	245	112.50	0.74	27 60	18.90	I_N = 53 4A
	for E/M workshop stores, street/Main gate Lighting	B	245	131.70	0.70	32.10	21 60	
10	MLDB S/S 2B	R	243	128 60	0 81	31.20	22 60	
	(Kiln Feed Area)	Y	241	141 00	0.64	33 80	21.20	I_N = 0
		B	244	108.30	0 60	26 70	15 65	
11	MLDB	R	-	-	-	-	-	Being fed from
	S/S 2 & 2 A	Y	-	-	-	-	-	kiln feed area
	Cooler + ESP area	B	-	-	-	-	-	(Sr No 10 above)
	Total						514 33	Excluding ACR load

Appendix - 8/5 contd.

PLANT : Colony

Date : 24 / 12 / 96
Time : 19.35 Hrs

Sl.No	L.D.B.Details	Ph	Measured					Remarks
			Volt	Amp	Cosϕ	kVA	kW	
1	ACW Canteen S/S-4	R	233	15 70	0.91	3.71	3.35	I_N could not be measured for difficult access
		Y	233	35 00	0.96	8 56	8.40	
		B	233	28 70	0.93	6.25	6.07	
2	Street Light S/S-4	R	233	8 50	0.69	2.00	1 49	-
		Y	233	8.70	0.69	2.03	1.42	
		B	233	9.00	0.69	2.08	1.49	
3	New E type Houses S/S - 4	R	233	74 40	0 95	17.28	16.60	I_N = 20.5 A
		Y	232	38 20	0 95	9.14	8.90	
		B	233	52 50	0.94	12.15	11.53	
4	Lagoon Guest House	R	232	44 30	0.98	8 80	8.73	I_N = 25.4 A S/S -4 Automatic Voltage Stabiliser (750 kVA) newly installed.
		Y	232	25 90	0.93	6.10	5.40	
		B	232	39 50	0 96	9 20	8.80	
5	'F' type S/S	R	241	594 00	0.93	142.20	138.30	I_N = 95.8 A
		Y	241	468 00	0.92	111.60	105.30	
		B	242	498.00	0.92	122.70	117.00	
6	'C' type /'D' Type Sub-station	R	228	248.70	0.93	56.70	54.00	I_N = 44.8 A Automatic Voltage Stabiliser (750 kVA) newly installed
		Y	229	185.40	0.91	43.68	40.20	
		B	229	181.80	0.90	41.28	37.98	

Appendix - 8/5 contd..

Sl.No	L.D.B.Details	Ph	Measured					Remarks
			Volt	Amp	Cosϕ	kVA	kW	
7	Sub-Station No.3	R	241	51.50	0 88	12.36	10.89	
	(TU1) 'G' type	Y	238	57 60	0.98	13.70	13.50	I_N = 20 4 A
	Module Fp8	B	244	36.00	0.95	9 60	9 20	
8	Sub-Station No.3	R	239	82.50	0 94	21.10	20 00	
	(TU1) 'G' type	Y	239	122.60	0 96	31.00	28.50	I_N = 18 3 A
	Module Fp10	B	239	110.40	0.92	27.50	25.10	
9	Sub-Station No.3	R	238	38 20	0 90	9.20	8.50	
	(TU1) 'G' type	Y	238	38 20	0.90	9 20	8.50	I_N = 11 7 A
	Module Fp11	B	238	38 20	0 90	9 20	8.50	
10	Sub-Station No.3	R	238	43 80	0.87	8 16	7 10	
	(TU1) 'G' type	Y	238	43 20	0.87	8 10	7 00	I_N = 12 1 A
	Module above Fp-11	B	238	44 00	0.87	8 16	7 10	
11	Sub-Station No 3	R	240	16 40	0 84	3 88	3 06	
	(TU1) 'G' type	Y	240	17 40	0 86	4 20	3 60	I_N = 3 2 A
	Module Fp13	B	240	18 20	0 91	4 40	3.90	
12	Sub-Station No.3	R	243	47 40	0 86	11.74	10.35	
	(TU1) 'G' type	Y	243	47 40	0 86	11.71	10.10	I_N = 10 3 A
	Module Fp14	B	243	47 40	0 86	11.60	10.30	
TOTAL							770.16	

APPENDIX - 8/6

LUX LEVEL MEASUREMENTS

PHASE - I

Sl No	Location details	Measured Lux Level	Remarks
1	Ph-I DBC Area	42/38/65	Maintenance required
2	Hammer Mill Area	45/60	-
3	Coal feed platform	26/32	Better Level required
4	Kiln Cooler fan W1K10	41/56	-
5	W1K16	45	HPSV fittings cleaning required
6	Kiln Compressor Room	15/27	-
7	Clinker Silo	23/32/27	Flood lights are dust covered
8	R1M01	42/34	-
9	Kiln Main Drive	26/35	-
10	Preheating Area	27/32/24	-
11	Area of Parking between Kiln1 & CCR bldg.	10-15	High Mast lighting can be used

Appendix - 8/6 contd .

PLANT - SUB STATION PH - I

Sl No	Location details	Measured Lux Level	Remarks
1	H P C. Ground floor between panel 1	82/61/70	-
2	H P C. Ground floor between panel 1	42/26	-
3	Ist floor between panel	103/84	-
4	Ist floor between panel	40/51	-
5	H P.C. 2A PLC Room	107	-
6	H.P C 2A Ist Floor between panel 1	70/46/29	-
7	H P.C. 2A behind panel 1	48/36	-
8	H P C 2A Ground Floor	60/52	-
9	H P C 2A Ist Floor behind panel	101/92	-
10	H P C 2A Ist Floor behind panel	37/24	-
11	H P C -1 Ground floor	56/69/23	-
12	H P C. - 1 Ist floor	96/107/73	-
13	H P C PLC Cap. room	70/24	-
MISCELLANEOUS			
14	Panel front	80/65/87	
15	Cap room/battery room	56/45	

Appendix - 8/6 contd.

PHASE - II

Sl No	Location details	Measured Lux Level	Remarks
1	Elect /Mech Office	32/38	Entrance Lobby
2	Office	79/92/43/81/92	Mirror Reflector can increase lux level
3	Officers Cabin	99/147	-
4	E/M Computer Room	95/62	Mostly cleaning of cover required
5	Civil Office	-	Closed
6	Civil Office Staircase	51	-
7	DBC Traction floor	59/65	Phase - II
8	DBC Staircase	80/110	-
9	DBC Tail End.	40	-
10	DBC Tunnel	35/64/78/136	Well glass fittings removed for HPSV - 70W lamps and fully covered by dust
11	Hammer Mill Motor	16	
12	Inlet W2K17 (K86)	48	HPSV focus totally dust (2 nos) covered Some are not working. Lowering height possible
13	W2K51 Drag chain Tail end	287/65	-
14	W2K03 (Folax Cooler) Front end	129/10	Dust accumulation
15	W2K04 Front	40	-
16	Solenoid control panel	33/15/26	Tube Lights prevailing
17	Kiln Operator's Room	78	-
18	Staircase for Atox Mill	22	-
19	Atox Coal Mill Platform	90-60-180	-
20	K2A01 Control Board	63	T/L & HPSV combination
21	Burner Platform (K2SO2)/ W2U07	72/32/21	-

Appendix - 8/6 contd.

Sl. No.	Location details	Measured Lux Level	Remarks
22	Burner Platform Window	50	One HPSV fitting not working
23	Coal Screw Platform	30/15	3 nos HPSV (focus) not working
24	K2M03	20/49/41	-
25	K2S03 Platform	26	-
26	K2T01 Platform	20	-
27	Fire Extinguisher Storage	31/52	Tubes require cleaning
28	Compressor Rooms	15/27/20/10	Few Compressors are running
29	S/S Transformer T22 Bay	37	Focus used
30	Front Road of - T2A1	24	250W HPSV can be equally distributed for 2X125W
31	S/S 2-2A	70-75	-
32	Cooler II - ESP room	-	Room Closed Tubes are 'ON'
33	W2P31 Platform	45/15/40	Fluorescent fitting require cleaning
34	General Shift Office (Elect) Ph-II	49	-
35	Pump House	46/12/22	Double T/L fitting (casing to be cleaned)
36	Pump House Area Outside	10	250W HPSV focus Dust accumulation Require cleaning
37	Envirocare Room	85/16	MCC portion T/L to be attended critical location not illuminated
38	Pumping Area (Ph-II) outside	17/4	-
39	Compressor (Screw) House	32/7/6	Not in operation 3/4 nos 250W/70W HPSV left on

Appendix - 8/6 contd..

Sl No	Location details	Measured Lux Level	Remarks
40	S/S 2B Transformer T2B1 Yard	15/10	Illumination required to be strengthened
41	S/S 2B Entrance + L.R S	93/30	10 Single T/L in not working condition
42	Panelfront	100	-
43	Kiln ESP fan platform	16/22	-
44	Iron Ore & Shale Yard	15	Increase of Illumination required
45	Stacker (operator's room)	10/45	Cleaning of Tube Light required
46	R2M03(Capacitor + L R S) Platform	18/30/18	-
47	S/S1 Transformer yard	-	No Light. 1 Tube Light not working. Required to put light fixtures
48	Rest Room, Raw Mill	41	-
49	Ball Mill	60/33/18/17	HPSV at heights require maintenance
50	R2P05 Platform	20/34/5	Shadow persisting
51	J2J03 Platform	39/32/10	-
52	J2J01 Platform	30/20/16	HPSV (focus) not working
53	Preheater (gr flr)	10/30	-
54	Silo ((gr flr)	15-30	-
55	Aeration flr	66/63/20	-
56	Lift Entrance	-	Light fitting required
57	Silo Ist floor	75	-
	2nd floor	20/76	-
	3rd floor	15/40	-
	4th floor	16/140	-
	5th floor	6/20	-
	6th floor	60	-
58	Kiln Main Drive Platform	120	-

Appendix - 8/6 contd .

PLANT - SUB STATION PH - II

Sl. No	Location details	Measured Lux Level	Remarks
1	S/S 2 & 2 A between panels (Ground floor)	71/63	Tubes are `ON' and few require replacement
2	Behind Panels (gr flr)	36/96	-
3	Between Panel (Ist flr)	40/42	-
4	Behind Panel (Ist flr)	45	-
5	Inverter Room (PLC)	46/160/50	Double fixtures kept `ON' during day also
6	S/S 2B Panel front (Gr flr)	100/77	-
7	S/S 2B, Behind Panel	47/40	-
8	S/S 2B Panel front (Ist flr)/ Battery room	101/76/38	-
9	S/S 2B, Behind Panel (Ist flr.) / SPRS / capacitor room	150/50/40	-
10	S/S 1 Entrance	26	-
11	S/S1 / gr. flr Between Panels /Panel front	60/170	-
12	S/S1 gr flr Behind panel	40	-
13	S/S 1 First Floor Between Panels / Cap room / Battery Room	78/15/36	Cleaning of T/L & Fixtures required
14	Ist flr Behind panel	80	-

Appendix - 8/6 contd.

CCR Building

Sl. No	Location details	Measured Lux Level	Remarks
1	CCR Entrance / Time M/c	15/25	Required better level of Illumination. Replacement of acrylic sheets required Day time 'off' can be arranged
2	CCR Ground floor Toilet	35	Another Toilet Lighting line to be checked as tubes not working
3	CCR ground floor Office corridor Under the Tubes Between the Tubes	 88 22	 - -
4	Granulometry Test Room Weigh M/c Crusher	 42 80/81	 - -
5	Mess	55	
6	Physical Lab - 1 Writing Table Working Table	 78 60/95/102/64	 - -
7	Physical Lab Writing Table Test Bed Crushing Chamber UTS m/c. compr.	 82 56/68 15 68	-
8	Kiln 2 SCR Room Front of 5 kVA system Data Logger SCR Rear	 32 52/40	Replacement of pink tubes necessary
9	Kiln 1 SCR Room MCC /SCR Front SCR Rear	68/34/06	In rear portion strengthen illumination
10	AC Plant shift room	35	-
11	AC plant A.C1 M/C. MCC (Front) Near Pr. gauge	 70 59 32	-
12	CCR Office	111	-

Appendix - 8/6 contd..

Sl. No.	Location details	Measured Lux Level	Remarks
13	CCR Ph-1 Control Panel desk	26/31/36	Pink Tubes required to be replaced Tubes kept off to avoid reflection on screen
14	CCR Ph-1 Control Panel Printer	101	-
15	CCR Ph-2 Control Panel Desk Near Operator	21/12/26 80/112	Tubes kept 'off' to avoid glare & reflection
16	CCR Entrance	90	-
17	PLC Room	220/170/220	-
18	QC X Lab	51/60	-
19	QC X Lab Computer/ Spectrometer	21/20/105	-
20	Chemical Lab near calorie meter	186	During night or if no occupancy, Tubes can be put 'off'
21	Chemical Lab Work Desk	126/86	During night or if no occupancy, Tubes can be put 'off'
22	Chemical Lab New Oven	92	During night or if no occupancy, Tubes can be put 'off'
23	Chemical Lab near Carbolite	62/92	During night or if no occupancy, Tubes can be put 'off'
24	Process Control Dept.	200/179	-
25	Inst. Shift Room Working Table	124	-
26	Inst. Shift Room Shift Table	63	-
27	2nd Floor Hall near Staircase	20	-
28	Ist Floor Reception	92	-
29	KYP K's Cabin/PA's table/ Computer	138/92 42/75	During non occupancy, can be switched off except for corridor

Appendix - 8/6 contd..

Sl No	Location Details	Measured Lux Level	Remarks
30	Pantry	75	-
31	Project Engg & Development Dept	65/68	Switch 'off' during non occupancy Strengthen illumination by use of proper reflector & maintenance
32	Technical Services	55/49/31	——do——
33	Ist Floor Hall near Staircase	97	-
MAIN GATE			
34	Distribution dept Main	65-80	Switch 'off' when not occupied
35	Manager's Cabin	65/91/116	——do——
36	Computer Room & Despatch Section	105/88	——do——
37	Despatch (Security) Desk	69	——do——
38	Time Office	90/107	Instead of 2 x 500 W HPSV lamps, 4 x 70 W HPSV lamps at regular intervals can be arranged for proper entrance lighting
39	Security Office	119/205	-
40	Main Entrance Gate	23/24	HPSV focus used
PACKING PLANT			
41	PH-I Packing Plant M/c 4	27/30	-
42	PH-1 Packing plant M/c.3	27/30	-
43	Shift room	68	-
44	Central Control room	23/27	Maintenance of luminaires required
45	Compressor Room	6/11/35	HPSV High Bay fittings require proper distribution & maintenance
46	MCC Room /Table/PCC front /Welding Panel/Behind Panel 5.1	102/34/10/70/36	HPMV & HPSV along with T/L are existing Reduction of height for tubes & proper distribution required
47	Main Corridor Packing Plant	07	-

Appendix - 8/6 contd

Sl No	Location Details	Measured Lux Level	Remarks
MISCELLANEOUS			
48	Garage Office/Trench/ Toolbox store area/Working area	113/480/23/2 1-22-23	Task Light in use
49	Mechanical Tool Room Lathe 7/ drill m/c.9/ lathe 4/ grinding m/c	1800/601/557 -126/360	Task Light being used Switch 'off' partly (2/3 rd) of main hall (18 X 250W HPSV) in night shift, when not occupied by adopting zig zag connection
50	Mechanical Workshop planning room	116	-
CEMENT MILL			
51	Cement Mill HPC-3 Shift Room / PCC/MCC(rear)PCC(rear) Ground floor MCC/MCC Front /Battery Room Ist flr.	89/55/27/148 37/22/49/80	Replace tube glowing pink Tube require redistribution by shifting from rear wall
52	Cement Mill 3 & 4 PCC front PCC rear	46/94 45/181	Replace pink tube
53	Cement Mill MCC first floor/Battery room	40-80/17	-
54	Z3 MO3 Plat form	40/51	-
55	Z4M04 plant form	61/21	-
56	Z2 U15 Compressor /Bay	101/40	-
57	Z1MO1 & Z2 MO1/ Lubrication	15-20/90-95	Tube fitting require maintenance
58	Ball mill cement ph1 & 2 shift room	54	-
59	I L trunion bearing HP/LP pump room	75	-
60	Cement PH1 & 2 Ball mill	66	-
61	Compressor room. Cement Mill Ph-2& Battery room	20/10/24/35	Lower tube light
62	" First floor	13/19/71	-

APPENDIX - 8/7

ENERGY SAVINGS BY VOLTAGE CONTROLLER

Total lighting load (as measured) include colony domestic loads = 1320 kW

Present voltage level observed = 233 Volts and above

If voltage level is reduced by 8 to 10% (i.e. 210 -220 Volts) then 10-15% energy savings can be achieved.

∴ Energy savings per annum = 132 x 12 x 330 days (taking 10% savings)

= 522720 units

Cost of energy savings per annum = Rs.15.68 lakh/year

To implement above proposal the plant is required to put separate lighting transformer in appropriate load centres.

However during system study following transformers (presently underloaded) are released for use as lighting transformer exclusively.

1 X 1600 kVA Transformer	-	Cement Mill (T32)
1 X 1500 kVA Transformer	-	HPC - 4
1 X 750 kVA Transformer	-	Township
1 X 500 kVA Transformer	-	Mines

The above transformers also can cater to 40 x 25 kVA welding sets during annual plant maintenance due to enough transformation capacity available.

Hence by redeploying :

⇨ 2 x1600 kVA & 1 x 750 kVA for plant lighting,
1 x 500 kVA for Colony lighting

Investment A/C capital Equipment	=	Nil
For modification & Others (e.g. cabling/panelling etc.)	=	Rs.15.00 Lakhs
Total Investment required	=	Rs.15 Lakhs
Simple payback period	=	1 year

Added Benefit } ➢ Longer life of luminaires
} ➢ Lesser replacement cost of material and man hour

APPENDIX - 8/8

LUMINAIRES INVENTORY CONSUMPTION DETAILS AS ON 1993-96

Description	Stock Qty	Consumption 1996-97 (Till Dec'96)	Consumption 1995-96	Consumption 1994-95	Consumption 1993-94
Choke for 70W-HPSV Lamp Fitting	0 00	0 00	0.00	1.00	95.00
HPMV Choke	0 00	0 00	0.00	0 00	0 00
Choke 250W HPSV Lamp	0,00	34 00	32.00	1.00	62.00
Tube Light 4' X 36W	-143 00	1794 00	1977 00	1842.00	2015.00
T L. Choke 40W	71 00	846 00	838 00	807.00	953.00
HPSV Lamp 70W with Built in Ignitor and Snap Starter	-10.00	871 00	764 00	682.00	626.00
HPMV Lamp 125 W	4 00	0 00	0 00	6 00	0.00
HPMV Lamp 250W with Ignitor	21 00	147 00	120.00	143 00	152 00

APPENDIX - 8/9

ENERGY SAVINGS BY SWITCHING OFF THROUGH TIMERS

1. Number of tubelights present in substation (as derived from Appendix - 8/2). = 961

2. Number of tubelights in cable trenches (Approximate cable trench (underground) length is 1260 M and distance between two tubes are 1.9 M) = 660

Presently all Substation tubes are left on 24 hours a day and in cable trenches at least 60% tubes are left 'ON' throughout inspite of having local switches at many places / locations.

Annual energy consumption by above = (845 + 396) x 40 W x 0.8 x 24 x 330

= 3,14,519 kWh

PROPOSAL

75% of above tubes can be switched 'OFF' during the day through TIMER /BYPASS circuit.

Hence annual energy consumption by above system = (314519/2) + (1/4) *(314519/2)

= 1,96,574 kWh

Therefore annual energy savings = 1,17,945 kWh

Cost of annual energy savings = Rs.3.54 Lakhs

Cost of implementation (approximately 15 points @ Rs.15,000/-) = Rs.2.25 Lakhs

Simple payback period = 0.65 years

APPENDIX - 8/10

ENERGY SAVINGS THROUGH SWITCHING OFF DURING DAY TIME

1. a. No. of tubes in U1U03 clinker belt (top) = 52
   b. No. of 70 W HPSV in U1U03 clinker belt (top) = 4

2. a. No. of 70 W HPSV in Ph-7 New coal crusher = 26
   b. No. of 250 W HPSV in Ph-7 New coal crusher = 4

3. No. of 70 W HPSV in DBC U2J08 (Topend) = 20

4. No. of 250 W HPSV in gypsum yard (Right side) = 11

5. No. of 70 W HPSV in Phase - I pipe conveyor = 37

Presently during the study it was observed that above fixtures are left 'ON' even during day time when no one is testing/maintaining.

Annual energy wasted by above fixtures alone = 11,920 W x 12 x 0.6 x 330

= 28,322 kWh

This can be prevented by "SWITCHING OFF" during the day.

Annual energy savings = 28,322 kWh

Cost of energy savings = Rs.0.85 lakhs

Cost of investment (towards promotional material) = Rs.1.00 lakhs

Simple payback period = 1 year

CASE STUDY FOR INSTALLING ELECTRONIC CHOKES FOR FLUORESCENT TUBES

Energy consumed by a single tubelight fitting with ordinary choke	=	55 W
Energy consumed by the light fitting after replacement with electronic choke	=	45 W
Total No. of tubelights in airconditioned areas (Approximate)	=	1800
Annual energy savings	=	$\frac{10 \times 1800 \times 12 \times 330}{1000}$
	=	71,280 kWh
Cost of savings per annum (@ Rs.3.per unit)	=	Rs.2.14 Lakhs
Cost of one electronic choke	=	Rs.300/-
Cost of implementation	=	Rs.5.40 Lakhs
Simple payback period	=	2.5 years

NOTE : This proposal can be taken as trial based option.

APPENDIX - 10/1

FREE AIR DELIVERY CAPACITY TEST

All compressors are designed to deliver a certain quantity of air per minute at a specified pressure. Normally compressor capacity is specified in terms of cubic feet or cubic metres per minute of free air at a specific delivery pressure For example, 30 m^3/min at 7.0 bar compressor sucks 30 m^3/min of free air from atmosphere at ambient temperature and compresses to 7.0 bar delivery pressure. During compressor commissioning, FAD test is conducted and the system will be handed over to the customer. Due to poor maintenance or ageing of compressor, sometimes it may not deliver the specified quantity of air, even though it consumes same power Hence FAD test should be conducted periodically to confirm whether compressor is working at its rated capacity or not.

1. FAD Test by Pump Up Method

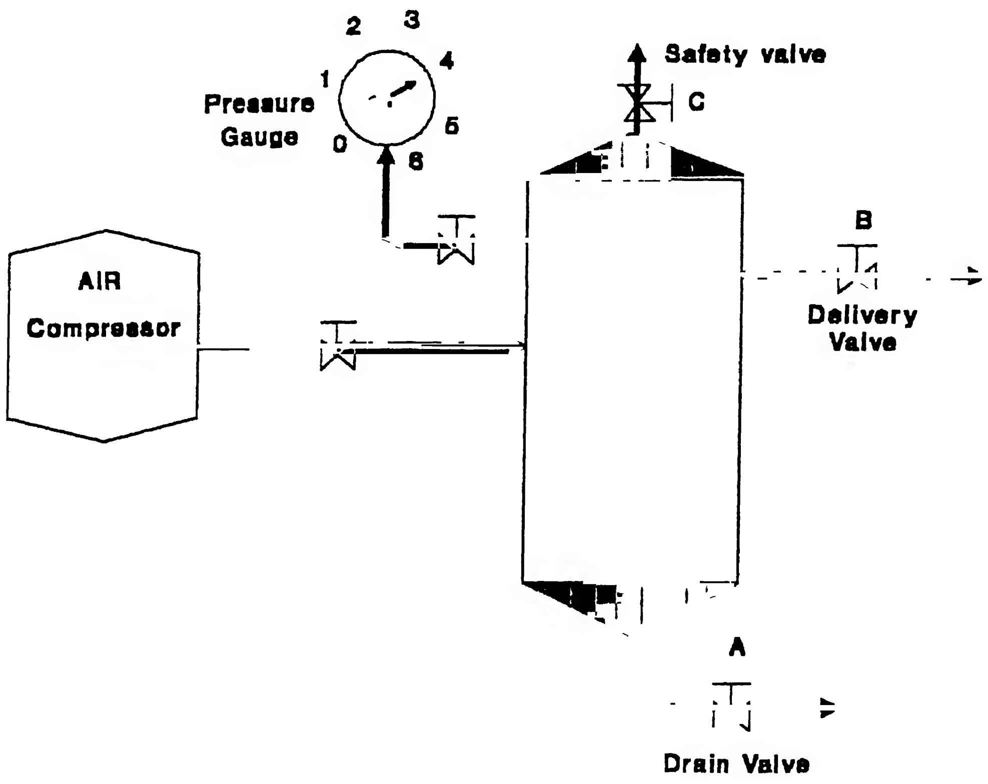
It is calculated by measuring the time taken to fill air receiver upto its designed pressure. By knowing receiver volume, interconnecting pipe line volume and outlet air temperature, it is possible to estimate the existing FAD capacity

Steps are given below

1. Switch off compressor
2. Open receiver drain valve (Valve A)
3. Wait until the air pressure in the receiver becomes zero
4. Close receiver air delivery valve, safety valve and drain valve(Valves A,B & C)
5. Start compressor and load it, simultaneously start the stop watch
6. Switch off compressor or note down the time at which compressor starts unloading. Note the pressure also.
7. Measure outlet air temperature
8. Calculate volume of air receiver and inter connecting pipe lines

Appendix - 10/1 contd..

FREE AIR DELIVERY CAPACITY



Appendix - 10/1 contd..

Substitute all values in the following formula -

$$\text{FAD capacity in } m^3/\text{min} = \frac{P_d}{P_s} \times \frac{T_i}{T_o} \times \frac{V}{t}$$

Where,

V = Volume of air receiver+interconnecting pipelines in m^3

t = Time taken to fill receiver in minutes

P_d = Cut off or final air pressure in kg/cm^2

T_o = Compressed air exit temp. in K

T_i = Inlet air temperature K

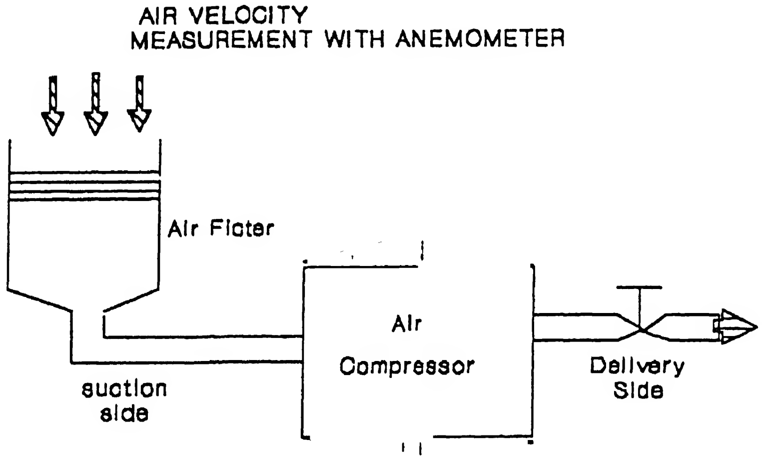
P_s = Atmospheric air pressure in kg/cm^2

2. **Suction Velocity Method**

Using anemometer, measure the average air velocity at the compressor suction side during compressor loading period (if required, suction hood may be removed and suction duct can be extended using card board of same diameter to facilitate taking measurements)

Appendix - 10/1 contd .

FAD ASSESSMENT - SUCTION VELOCITY METHOD



FAD capacity in m^3/min = A x B

Where A = Suction air velocity in m/min

B = Area of cross section of inlet duct in m^2

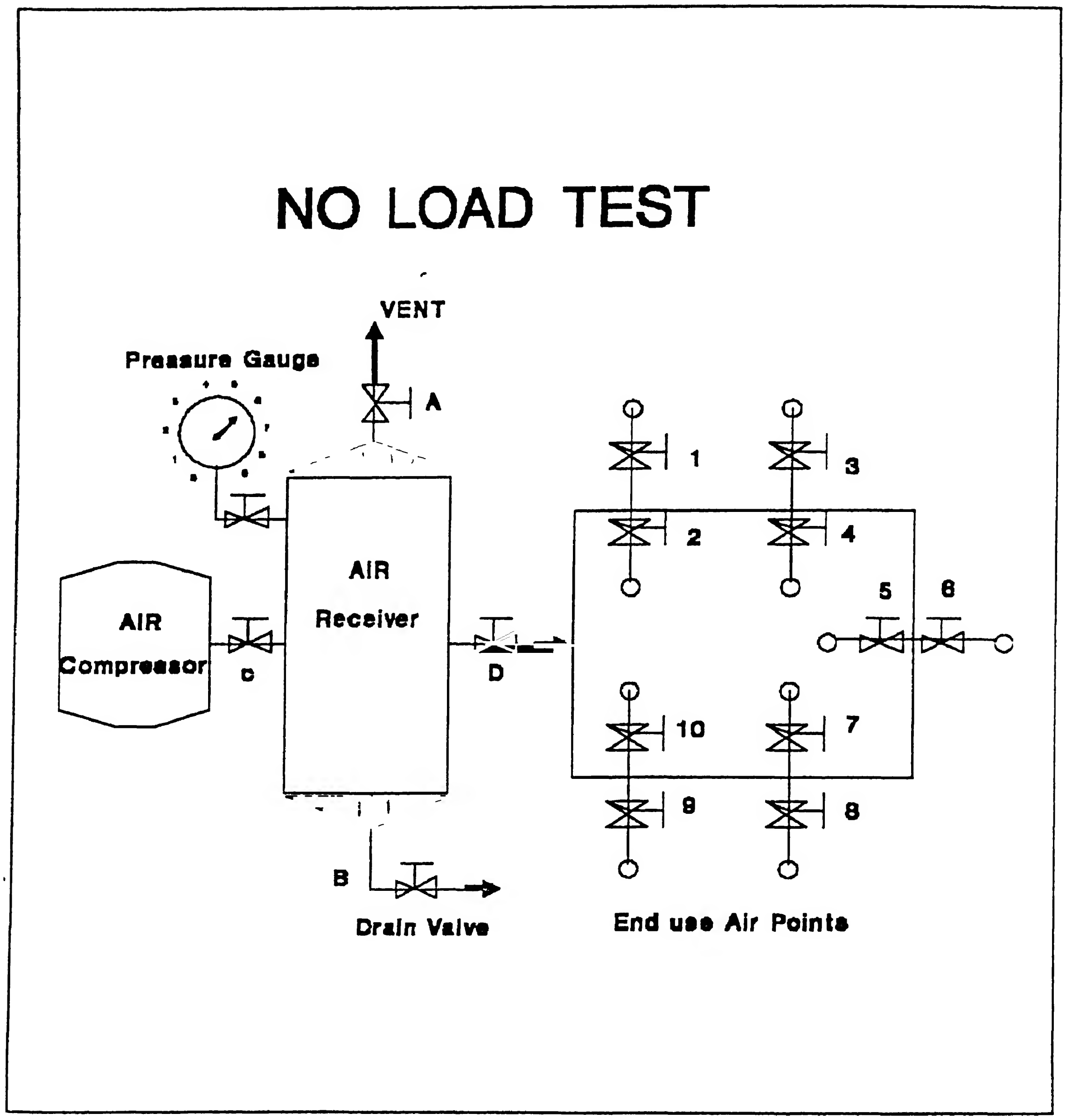
APPENDIX - 10/2

COMPRESSED AIR LEAKAGE (NO-LOAD) TEST

Compressed air leaks obviously waste energy, and also reduce the effective capacity of compressor plant and may, in extreme cases, reduce significantly the performance of the end use equipment. Ideally speaking, compressed air system should not have any leaks at all but in practice it is rather difficult to have a zero leakage system. Depending upon the industry and type of air usage patterns upto 10% air leakage is allowed. In almost all industries using compressed air systems, one can hear a hissing sound from leaking pipe joints, valves, couplings, air regulators and other leak - prone areas. Leak check detectors can also be used to locate compressed air leakage points. Generally, the compressed air leakage is ignored as nobody quantifies the air wastage No load test should be conducted periodically, when the plant is not in operation (lunch hours, during plant maintenance period, etc.) in order to quantify the air leakage and keep it to an acceptable minimum level Procedure for leakage test is described below Refer the figure below :

Step 1 Switch off the compressor
Step 2. Close air receiver outlet and drain valves (Valves A and B)
Step 3. Open compressor discharge and air receiver discharge valves (Valves C & D)
Step 4 Close all end use points (Valves 1 to 10)
Step 5 Start compressor and allow the pressure to build up
Step 6. Note time when it unloads
Step 7 Note time when it loads
Step 8 Repeat this exercise four or five times
Step 9 Switch off compressor

Appendix - 10/2 contd..



Total **system leakage** can be calculated by substituting loading and unloading times in the equation given below

$$L = \frac{Q \times T}{(T + t)}$$

Where,

L = Total system leakage in m^3/min

Q = Actual free air delivery capacity of compressor in m^3/min

T = On load time in minutes

t = Off load time in minutes

Appendix - 10/2 contd

Power wasted due to leakage (kW)

= Total system leakage x Sp Energy consumption

Annual energy wastage (Lakh kWh)

= Total system leakage x Sp Energy consumption x Annual operating hours

If leakage is more than the allowable limits, locate and arrest leakages immediately

APPENDIX - 10/3

INSTRUMENTATION FOR COMPRESSED AIR SYSTEMS

1. Vane Type Anemometer

This instrument is used for measuring velocity of inlet air to compressor and thereby calculating FAD by knowing the inlet area. The vane rotates when placed in an air stream, the speed of the rotation being related to the air velocity. Velocities in the range of 0 12 m/s to 30 m/s can be measured with an accuracy better than 3% of the instrument range in use except at very low velocities A digital indicator is attached to the anemometer which displays the air velocity directly

The precaution to be taken here is to ensure that the inlet air velocity does not exceed the measuring range of the instrument This instrument is also used to measure air flow in Fans, Root blowers, Air Handling Units (AHU), etc

2. Pressure Gauge (Bourdon type - calibrated)

The operating pressure of compressors, on-off pressure settings and pressure drop in distribution lines can be measured using Bourdon type pressure gauges

3. Temperature Gauge

The operating temperature of air and water on inlet and outlet sides can be known. The temperature before / after inter-coolers and after-coolers can also be known.

Appendix - 10/3 contd..

4. **Hygrometer**

This is a portable electronic instrument with a digital indicator and a long probe to measure the dry bulb and wet bulb temperatures and percentage relative humidity of ambient air or compressor - inlet air. The water content in the air at compressor inlet can be estimated.

5. **Digitial Temperature Indicator with sensors**

This is a digital type meter provided with surface contact type thermocouple This is used to measure the cooling water inlet and outlet temperature, inlet and outlet air temperature at different stages of compression, inter-coolers and after-coolers

6. **Leak Check Detector**

This is a portable electronic instrument which can detect minute leakage of compressed air from leaking pipes, valves, traps, etc It has an in-built amplifier and a display screen. The intensity of leakage is displayed on the LED screen. It is suitable for locating overground air leakages. It cannot quantify the air leakage.

7. **Power Analyser**

It is a versatile instrument to measure various electrical parameters such as kW, kVA, Power Factor, Volts, Current and Frequency. These parameters are used to evaluate the percentage loading on motors and then to infer the operating efficiency

8. **Stop Watch**

9. **Measuring Tape**

APPENDIX - 11/1

LIST OF SUPPLIERS AND RETROFITS

Eqpt./Retrofit	Manufacturer/Suppliers
Lighting	Beblec (India) Ltd 126, Sipcot complex Hosur 635 126, Tamilnadu
	Electronics India 238/A, 10th Main Road Nagendra Block, BSK II Stage Bangalore 560 050
Capacitors	Asian Electronics Ltd. D-11, Road No 28 Wagle Industrial Estate Thane - 400 604
	<u>Marketed by</u>
	Mysore Sales Intl Ltd Industrial Products Dvn MSIL House, 36, Cunningham Road Bangalore 560 052
	Meher Capacitors Pvt Ltd. 16(K), Attibele Industrial Area Neralur 562 107 Bangalore District.
	<u>Marketed by</u>
	Larsen & Toubro Limited P O Box 119, Pune 411 001

Appendix - 11/1 contd..

Eqpt./Retrofit	Manufacturer/Suppliers
	Prabhodan Capacitors Mfg.by Seva Engg Works Saswadi, Pune
	Crompton Greaves Ltd. Dr E Moses Road Worli, Bombay 400 018
Energy Efficient Motors	Siemens Limited Jyothi Mahal II Floor St Marks Road, Bangalore 560 001
	Crompton Greaves Limited Machine I Division Dr E Moses Road Worli, Bombay 400 018
Variable Speed Drives	Asea Brown Boveri Ltd Sona Towers, 71, Miller Road Bangalore 560 052
	Kirloskar Electric Co. Ltd. Unit-IV, Belawadi Indl Area Mysore 510 005
	Siemens Limited Jyothi Mahal, III Floor -49 St Marks Road, Bangalore 560 001
	Allen Bradley Ltd. C-11, Site-4 Industrial Area, Shahibad Pin 201 010

Appendix - 11/1 contd .

Eqpt./Retrofit	Manufacturer/Suppliers
Soft Starters	Jeltron Instruments (I) (P) Ltd 6-3-248/F Road No.1 Banjara Hills Hyderabad 500 034
	Jayshree Electro Devices (P) Ltd 101, Prabhodhan Apartment 64/9, Erandewane, Pune 411 004
	Bharat Bijilee Ltd. Industrial Electronic Division 501-502, Swastik Chambers Chembur, Bombay 400 071
	Control Techniques (I) Ltd 117-B, Developed Plot Industrial Estate Perungudi, Madras 600 096
Timer Control Switch	Larsen & Toubro Limited Post Box No.119 Poona 411 001
Photo Sensitive Switch	Govt Tool Room Training Centre, Rajajinagar Bangalore 560 044
Flow Meter (Compressed Air)	ITT Barton I Floor, Indra Palace, H block, Cannaught Place New Delhi 110 001

Appendix - 11/1 contd..

Eqpt./Retrofit	Manufacturer/Suppliers
	Kent Meters Ltd. Agent : L & T Limited Gulas Bhavan 6, Bahadur Shah Zafar Marg New Delhi 110 002
	J N Marshall Pvt Ltd. Bombay-Pune Road Kasarvadi, Pune 411 054
	Eureka Industrial Equipment Pvt Ltd. 258, Kalina Udyog Bhavan Prabhadevi, Bombay 400 025
Power Analyser (To measure kVA, kW, PF, V & A)	Microtek Instruments 40-A, I Main Road I Floor, CIT Nagar Madras 600 035
Fans/ Blowers	S M India Limited 42-A, Harrington Road Madras
	Andrew Yule Co Ltd. Engg Division Yule House, Clive Road Calcutta 700 001
	Asea Brown Boveri Ltd. Sona Towers, 71 Millers Road Bangalore 560 052

Appendix - 11/ 1 contd.

Eqpt./Retrofit	Manufacturer/Suppliers
Inlet Vane Guide Control	Asea Brown Boveri Ltd. Sona Towers, 71 Millers Road Bangalore 560 052
Lux Meter	Cocin Prakrito Instrumentation 16, Rajendra Nagar P O Mohan Nagar Ghaziabad 201 007
Anemometer	Microtech Instruments 40-A, I Main Road CIT Nagar, Madras 600 035
O_2 & CO_2 Analysers	J N Marshall Systems & Services P B No 37, Bombay Pune Road Kasarvadi, Pune 411 005
	Taylor Instrument Co (I) Ltd 14, Mathura Road PO Amarnagar, Faridabad
Star Delta Auto Controllers	Project & Supply A-605, Sunswept, Lokhandwala Complex Swami Samarth Nagar Four Bunglow, Andheri (W) Bombay 400 056
	Technovation Control & Power Systems 5, Savita Sangam Society Near Rajesh Apartment, Gotri Road Baroda 390 007
Compact Fluorescent Lamps	GE-Apar Lighting Maker Chambers 111, I Floor Nariman Point Bombay 400 021

Appendix - 11/1 contd..

Eqpt./Retrofit	Manufacturer/Suppliers
	Crompton Greaves Ltd. Lighting Division Dr E Moses Road Worli Bombay 400 018
Compressors	Kirloskar Pneumatic Co Ltd , Industrial Estate Hadaspur, Pune Maharashtra
	Ingersol Rand (I) Ltd., Rhome-Poulence House S K Ahiri Marg PO Box 9138 Bombay 400 025
	Hindustan Compressors Ltd. 18-A, New Market Begum Bridge Meerut 250 001
	Elgi Compressors India House, Trichy Road Coimbatore 641 018
	Consolidated Pneumatic Tool Co Ltd. 301-302, L B Sastri Marg Mulund, Bombay 400 001
	K G Khosla Compressors Ltd. 1, Deshbandhu Gupta Road New Delhi 110 055

Appendix - 11/1 contd

Eqpt./Retrofit	**Manufacturer/Suppliers**	
Moisture Separators for Compressed Air (Automatic drain valve)	Trident Industries 408, Sathy Road Ganapathy Coimbatore	Mktd by: Trident Electric Pvt Ltd # 133, I Floor, 11th cross Opp. Jeerige Bldg Malleswaram, Bangalore 3
	Prasad Machine Works 8/85, Nehru Nagar PO Kalaputti Coimbatore 641 035	
	Siemag Hi-tech Filters Pvt Ltd # 7, New Lata Apartments Jawahar Nagar, Goregaon (W) Bombay 400 062	
	Mercury Automatic Corpn. 8712, Arangung Near Palace Cinema Roshanera Road Delhi 110 007	
Fluid Coupling	Fluidomat Limited 7C-8J, Industrial Area A B Road, Dewas 455 001 (M P)	
Digital Thermometer and Temperature Indicators	Radix Sensor Pvt Ltd. B/34, 1st Ghanshyam Indl Estate Off. Veera Desai Road, Andheri (West) Bombay 400 058	

Appendix - 11/1 contd..

Eqpt./Retrofit	Manufacturer/Suppliers
FRP Blades For Cooling Towers	Parag Enterprises Pvt. Ltd. 43, Tarani Colony AB Road, Dewas Madya Pradesh 455 001
Low Cost Photo Cell Timer	Govt Tool room Training Centre, Electronic Section, Rajajinagar Indl. Estate, Bangalore 560 044
Voltage Controllers	Beblec (India) Ltd. 126, Sipcot Complex Hosur 635 126, Electronics India 238/A, 10th Main Road Nagendra Block, BSK II Stage, Bangalore 560 050
Synthetic Flat Belts	NTB International Ltd. A-302, Road No.32 Wagle Industrial Estate Thane - 400 604 Habasit Iakoka Ltd. Opp. Goldwins, Civil Aerodrome Post Coimbatore 641 014 Tamilnadu
Cogged Belts	Shail International 4-1, Shivsagar Apts SV Road Opp. Mulji Nagar Borivili (West), Bombay 400 092

Appendix - 11/1 contd.

Eqpt./Retrofit	Manufacturer/Suppliers
Fabricators of Copper Intercell Busbars, Flexibles	AVI Machine Spares Off B/24 Vraj Villa Ist Floor Amrutnagar, LBS Marg Ghatkopar Indl Estate Ghatkoar (W) Bombay 400 086 **Factory 1 :** B-15/a Ghatkopar Indl Estate, LBS Marg, Ghatkopar (W) Bombay 400 086 **Factory 2 :** 3, Hanuman Indl Estate Kastak Road, Wadala Bombay 400 031 **Factory 3 :** 886/c, GIDC Indl Estate Makarpura Baroda 390 010
	Mistry Prabudas Manji, Opp Mithal Industrial Estate, Andheri Kura Road Bombay 400 059 Ph 6341828 / 6343860
	B M Moonot & Neutronics Mfg Co Regd.Office Station View Bldg Chembur, Bombay 400 071

Appendix - 11/1 contd..

Eqpt./Retrofit	Manufacturer/Suppliers
	Works : 12-1 Marol Maroshi Road Opp State Bank of India, Andheri (East) Bombay 400 059 Tel 583749
	National Wire and Metal Industries Works & Admn Office : 1/2, Sonawala Estate, Sonawala Road Goregaon East Bombay 400 063 Tel 695718, 692032, 693603 Grams "CONDUCTOR" Bombay 400 063
Pumps	Allweiler Tushaco (I) Ltd. 201, Wadala Udyog Bhavan Naigaum Cross Road, Mumbai 400031
	Kirloskar Brothers Ltd Udyog Bhavan, Tilak Road Pune - 411 002
Spray Guns (Blow Guns)	Pneutech Engineering Unit.17, Ashok Indl Estate PB NO.7772, L B Shastri Marg Mulund, Mumbai 400 080
Pressure Recorders	J N Marshall Systems & Services P B No.37, Bombay Pune Road Kasarvadi, Pune 411 005

Appendix - 11/1 contd.

Eqpt./Retrofit	Manufacturer/Suppliers
Temperature Controller	Sonit Electronics 7, Shivsagar Society Krishnanagar, Near Super Steel Corpn Safed Pool, Pipe line, Mumbai 400 072
Gear Box	Shanthi Gears Limited 304-A, Trichy Road Singanallur, Coimbatore 641 005
Roots Blower	Kay International Pvt Ltd. 20th Mile, P O P.S.Rai Distt. Sonepat Haryana, India Economy Pneumatics Adarsh Ice & Cold Storage Compound Opp SNDT College B Z Patel Road, Off Marve Road Malad (W) Mumbai - 400 064
Digital Humidity & Temperature Indicator	Vaisala Sensor Systems P O Box 26, SF-00241 Helsinki, Finland Fax. 358 8949485
Sling Hygrometer	Lawerence & Mayo (P) Ltd. 4 - B, MG Road Bangalore 560 001

Appendix - 11/1 contd..

Eqpt./Retrofit	Manufacturer/Suppliers
Thermocouples	Toshniwal Bros Pvt. Ltd 37/4, Cunningham Road Cross Bangalore 560 052
Non Contact Temp. Indicator	Kane May Ltd. Swallowfield, Welwyn Garden City Hertfordshire AL6 1JP England Fax 0707 331202
Flexible Manometer (Water Column Differential pressure)	The British Rototherm Company Ltd Mragam, Port Talbot West Glamorgam SA 13 2 PW
Micro Mano Meter with Pitot Tube	AIR Instruments Resources Ltd. Monument Industrial Park Chalgrove, Oxford England OX9 7RW Ph (0865) 891190
Pressure Gauge	AR Enterprises N R Road Bangalore 560 001
Flue Gas Thermometer	Forebensons Engg. Ltd Plot No. A-19/2 & T - 4/2 IDA, Nacharam Hyderabad